Patents Form 1/77

Patents Act 1977
(Rule 16)

The Patent Office

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

GB 0228425.5

The Patent Office

Cardiff Road
Newport
South Wales
NP9 1RH

1. Your reference	CTV/P100245GB2
2. Patent application number *(The Patent Office will fill in this part)*	
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	Splashpower Limited St. John's Innovation Centre Cowley Road Cambridge CB4 0WS
Patents ADP number *(if you know it)*	
If the applicant is a corporate body, give the country/state of its incorporation	UK
4. Title of the invention	Improvements relating to contact-less power transfer
5. Name of your agent *(if you have one)*	Harrison Goddard Foote
"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Belgrave Hall Belgrave Street Leeds LS2 8DD
Patents ADP number *(if you know it)*	14571001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
	UK	0210886.8	13/5/2002
	UK	0213024.3	7/6/2002

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	0
Description	33
Claim *(s)*	7
Abstract	1
Drawing *(s)*	20

10. If you are also filing any of the following, state how many against each item.

Priority documents		
Translations of priority documents		
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*		
Request for preliminary examination and search *(Patents Form 9/77)*	1	
Request for substantive examination *(Patents Form 10/77)*		
Any other documents *(please specify)*	1	Cover letter, fee sheet

11. I/We request the grant of a patent on the basis of this application.

Signature

Date 6/12/2002

12. Name and daytime telephone number of person to contact in the United Kingdom

Chris Vaughan 0113 233 0100

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 0645 500505.*

b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

e) *Once you have filled in the form you must remember to sign and date it.*

f) *For details of the fee and ways to pay please contact the Patent Office.*

Patents Form 9/77

Patents Act 1977
(Rules 25, 28 & 32)

The Patent Office

Request for a preliminary examination and search

(See the notes on the back of this form)

The Patent Office

Cardiff Road
Newport
South Wales
NP9 1RH

1. Your reference — CTV/P100245GB2

2. Patent application number
(if you know it)

3. Full name of the or of each applicant — Splashpower Limited

4. Is this request for:

a) A preliminary examination and search under Section 17(1) for an international application which has been searched in the international phase? *(see note (f))*

b) A preliminary examination and search under Section 17(1) for any other application? — (b)

c) A supplementary search under Section 17(8)?

(d) A search of a further invention under Section 17(6)?

(Answer this question by writing (a), (b), (c) or (d)).
If your answer is (d), identify the invention to be searched by referring to the claims
(see note (c)).

5. Do you want any extra copies of any documents cited in the search report? — Yes
(see note (d))

If so, state how many and remember to pay the extra fee — One

6. Signature — Date 6/12/2002

7. Name and daytime telephone number of person to contact in the United Kingdom — Chris Vaughan — 0113 233 0100

Patents Form 10/77

Patents Act 1977
(Rule 33)

The Patent Office

Request for a substantive examination

(See the notes on the back of this form)

The Patent Office

Cardiff Road
Newport
South Wales
NP9 1RH

1. Your reference

CTV/P100245GB2

2. Patent application number
(if you know it)

3. Full name of the or of each applicant

Splashpower Limited

4. *(see note (c))*

I/We request substantive examination of this application.

Signature

Date

6/12/2002

5. Name and daytime telephone number of person to contact in the United Kingdom

Chris Vaughan - 0113 233 0100

IMPROVEMENTS RELATING TO CONTACT-LESS POWER TRANSFER

This invention relates to a new device and method for transferring power in a contact-less fashion.

Many of today's portable devices incorporate "secondary" power cells which can be recharged, saving the user the cost and inconvenience of regularly having to purchase new cells. Example devices include cellular telephones, laptop computers, the Palm 500 series of Personal Digital Assistants, electric shavers and electric toothbrushes. In some of these devices, it is possible to charge the cells via inductive coupling rather than direct electrical connection. Examples include the Braun Oral B Plak Control power toothbrush, the Panasonic Digital Cordless Phone Solution KX-PH15AL and the Panasonic multi-head men's shavers ES70/40 series.

Each of these devices typically has an adaptor or charger which takes power from mains electricity, a car cigarette lighter or other sources of power and converts it into a form suitable for charging the secondary cells. There are a number of problems associated with conventional means of powering or charging these devices:

- Both the characteristics of the cells within each device and the means of connecting to them vary considerably from manufacturer to manufacturer, and from device to device. Therefore users who own several such devices must also own several different adaptors. If users are going away on travel, they will have to bring their collection of chargers if they expect to use their devices during this time.

- These adaptors and chargers often require users to plug a connector into the device or to place the device into a stand causing inconvenience. If users fail to plug or place their device into a charger and it runs out of power, the device becomes useless and important data stored locally in the device might even be lost.

- In addition, most adaptors and chargers have to be plugged into mains sockets and hence if several are used together, they take up space in plug strips and create a messy and confusing tangle of wires.

- Besides the above problems with conventional methods of recharging devices, there are also practical problems associated with devices having an open electrical contact. For example, devices cannot be used in wet environments due to the possibility of corroding or shorting out the contacts and also they cannot be used in flammable gaseous environments due to the possibility of creating electrical sparks.

Chargers which use inductive charging remove the need to have open electrical contacts hence allowing the adaptor and device to be sealed and used in wet environments (for example the electric toothbrush as mentioned above is designed to be used in a bathroom). However such chargers still suffer from all other problems as described above. For example, the devices still need to be placed accurately into a charger such that the device and the charger are in a predefined relative position (See Figures 1a and 1b). The adaptors are still only designed specifically for a certain make and model of device and are still only capable of charging one device at a time. As a result, users still need to possess and manage a collection of different adaptors.

Universal chargers (such as the Maha MH-C777 Plus Universal charger) also exist such that battery packs of different shapes and characteristics can be removed from the device and charged using a single device. Whilst these universal chargers eliminate the need for having different chargers for different devices, they create even more inconvenience for the user in the sense that the battery packs first need to be removed, then the charger needs to be adjusted and the battery pack needs to be accurately positioned in or relative to the charger. In addition, time must be spent to determine the correct pair of battery pack metal contacts which the charger must use.

It is also known that patent US5959433: "Universal Inductive Battery Charger System" describes a non-contact battery charging system. The battery charger

described includes a single charging coil which creates magnetic flux lines which will induce an electrical current in a battery pack which may belong to cellular phones or laptop computers.

It is also known that patent US4873677: "Charging Apparatus for an Electronic Device" describes an apparatus for charging an electronic device which includes a pair of coils. This pair of coils is designed to operate in anti-phase such that magnetic flux lines are coupled from one coil to the other. An electronic device such as a watch can be placed on these two coils to receive power.

It is also known that patent US5952814: "Induction charging apparatus and an electronic device" describes an induction charger for charging a rechargeable battery. The shape of the external casing of the electronic device matches the internal shape of the charger thus allowing for accurate alignment of the primary and secondary coils.

It is also known that patent US 6,208,115: "Battery substitute pack" discloses a substitute battery pack which may be inductively recharged.

It is known that patent WO00/61400: "Device for Inductively Transmitting Electrical Power" discloses a means of transferring power inductively to conveyors.

It is known that patent WO9511545 "Inductive power pick-up coils" outlines a system for inductive powering of electric vehicles from a series of in-road flat primaries.

To overcome the limitations of inductive power transfer systems which require that secondary devices be axially aligned with the primary unit, one might propose that an obvious solution is to use a simple inductive power transfer system whereby the primary unit is capable of emitting an electromagnetic field over a large area (See Figure 2a). Users can simply place one or more devices to be recharged within range of the primary unit,. with no requirement to place them accurately. For example this

primary unit may consist of a coil encircling a large area. When a current flows through the coil, a large electromagnetic field is created and devices can be placed anywhere within this area. Although theoretically feasible, this method suffers from a number of drawbacks. Firstly, the intensity of electromagnetic emissions is governed by regulatory limits. This means that this method can only support power transfer at a low rate. In addition, there are many objects that can be affected by the presence of a large magnetic field. For example, data stored on credit cards maybe destroyed and objects made of metal will have induced therein eddy currents generating undesired heating effects.

To avoid the generation of large magnetic fields, one might suggest using an array of coils (See Figure 3) whereby only the coils needed are activated. This method is described in a paper published in the Journal of the Magnetics Society of Japan titled "Coil Shape in a Desk-type Contactless Power Station System" (29^{th} Nov 2001). In an embodiment of the multiple-coil concept, a sensing mechanism senses the relative location of the secondary device relative to the primary unit. A control system then activates the appropriate coils to deliver power to the secondary device in a localised fashion. Although this method provides a solution to the problems previously listed, it does so in a complicated and costly way. The degree to which the primary field can be localised is limited by the number of coils and hence the number of driving circuits used (i.e. the "resolution" of the primary unit). The cost associated a multiple-coil system would severely limit the commercial applications of this concept. Non-uniform field distribution is also a drawback. When all the coils are activated in the primary unit, they sum to an equivalent of a large coil, the magnetic field distribution of which is seen to exhibit a minimum at the centre of the coil.

None of the prior art solutions can satisfactorily address all of the problems that have been described. It would be convenient to have a solution which is capable of transferring power to portable devices with all of the following features and is cost effective to implement:

- Universality: a single primary unit which can supply power to different secondary devices with different power requirements thereby eliminating the need for a collection of different adaptors and chargers;
- Convenience: a single primary unit which allows secondary devices to be placed anywhere within an active vicinity thereby eliminating the need for plugging-in or placing secondary devices accurately relative to an adaptor or charger;
- Multiple-load: a single primary unit that can supply power to a number of secondary different devices with different power requirements at the same time;
- Flexibility for use in different environments: a single primary unit that can supply power to secondary devices such that no direct electrical contact is required thereby allowing for secondary devices and the primary unit itself to be used in wet, gaseous, clean and other atypical environments
- Low electromagnetic emissions: a primary unit that can deliver power in a manner that will minimize the intensity and size of the magnetic field generated

It is further to be appreciated that portable appliances are proliferating and they all need batteries to power them. Primary cells, or batteries of them, must be disposed of once used, which is expensive and environmentally unfriendly. Secondary cells or batteries can be recharged and used again and again.

Many portable devices have receptacles for cells of an industry-standard size and voltage, such as AA, AAA, C, D and PP3. This leaves the user free to choose whether to use primary or secondary cells, and of various types. Once depleted, secondary cells must typically be removed from the device and placed into a separate recharging unit. Alternatively, some portable devices do have recharging circuitry built-in, allowing cells to be recharged in-situ once the device is plugged-in to an external source of power.

It is inconvenient for the user to have to either remove cells from the device for recharging, or to have to plug the device into an external power source for recharging in-situ. It would be far preferable to be able to recharge the cells without doing either, by some non-contact means.

Some portable devices are capable of receiving power coupled inductively from a recharger, for example the Braun Oral B Plak Control toothbrush. Such portable devices typically have a custom, dedicated power-receiving module built-in to the device, which then interfaces with an internal standard cell or battery (which may or may not be removable).

However it would be convenient if the user could transform <u>any</u> portable device which accepts industry-standard cell sizes into an inductively-rechargeable device, simply by fitting inductively-rechargeable cells or batteries, which could then be recharged in-situ by placing the device onto an inductive recharger.

Examples of prior art include US 6,208,115, which discloses a substitute battery pack which may be inductively recharged.

According to a first aspect of the present invention, there is provided a system for transferring power without requiring direct electrical conductive contacts, the system comprising:

i) a primary unit having a substantially laminar surface with at least one electrical conductor that generates an electromagnetic field when a current flows therethrough and having an active area defined within a perimeter of the surface, the at least one conductor being arranged such that electromagnetic field lines generated by the at least one conductor are substantially parallel to the plane of the surface within the active area; and

ii) at least one secondary device including at least one electrical conductor;

wherein the active area of the primary unit has a perimeter large enough to surround the electrical conductor of the at least one secondary device in at least one orientation thereof substantially parallel to the surface of the primary unit in the active area, such that when the at least one secondary device is placed on or in proximity to the active area in a predetermined orientation, the electromagnetic field induces a current in the at least one conductor of the at least one secondary device.

According to a second aspect of the present invention, there is provided a primary unit for transferring power in a non-conductive manner to at least one secondary device including at least one electrical conductor, the primary unit having a substantially laminar surface with at least one electrical conductor that generates an electromagnetic field when a current flows therethrough and having an active area defined within a perimeter of the surface, the at least one conductor of the primary unit being arranged such that electromagnetic field lines generated by the at least one conductor of the primary unit are substantially parallel to a plane of the surface within the active area, and wherein the active area has a perimeter large enough to surround the conductor of the at least one secondary device in at least one orientation thereof substantially parallel to the surface of the primary unit in the active area.

According to a third aspect of the present invention, there is provided a method of transferring power in a non-conductive manner from a primary unit to a secondary device, the primary unit having a substantially laminar surface with at least one electrical conductor that generates an electromagnetic field when a current flows therethrough and having an active area defined within a perimeter of the surface, the at least one conductor being arranged such that electromagnetic field lines generated by the at least one conductor are substantially parallel to the plane of the surface within the active area, and the secondary device having at least one electrical conductor, wherein the active area has a perimeter large enough to surround the conductor of the at least one secondary device in at least one orientation thereof substantially parallel to the surface of the primary unit within the active area and

wherein flux lines of the electromagnetic field link with the conductor of the secondary device when this is placed on or in proximity to the active area.

According to a fourth aspect of the present invention, there is provided a secondary device for use with the system, unit or method of the first, second or third aspects, the secondary device including at least one electrical conductor, preferably having a substantially flat form factor.

The primary unit may include an integral power supply for the electrical conductor, or may be provided with means enabling the electrical conductor to be connected to an external power supply.

The at least one electrical conductor in the secondary device may be wound about a core that serves to concentrate flux therein. In particular, the core (where provided) may offer a path of least resistance to flux lines of the electromagnetic field generated by the primary unit. The core may be amorphous magnetically permeable material. In some embodiments, there is no need for an amorphous core.

The at least one conductor in the primary unit may be a coil, for example in the form of a length of wire or a printed strip, or may be in the form of a conductive plate of appropriate configuration. A preferred material is copper, although other conductive materials may be used as appropriate. It is to be understood that the term "coil" is here intended to encompass any appropriate electrical conductor forming an electrical circuit through which current may flow and thus generate an electromagnetic field. In particular, the "coil" need not be wound about a core or former or the like, but may be a simple or complex loop or equivalent structure.

The core in the secondary device, where provided, is preferably a high magnetic permeability core. The relative permeability of this core is preferably at least 100, even more preferably at least 500, and most preferably at least 1000, with magnitudes of at least 10,000 or 100,000 being particularly advantageous.

Preferably, the active area of the primary unit is large enough to accommodate the conductor and/or core of the secondary device in a plurality of orientations thereof. In a particularly preferred embodiment, the active area is large enough to accommodate the conductor and/or core of the secondary device in any orientation thereof. In this way, power transfer from the primary unit to the secondary device may be achieved without having to align the conductor and/or core of the secondary device in any particular direction when placing the secondary device on the surface of the primary unit.

The substantially laminar surface of the primary unit may be substantially planar, or may be curved or otherwise configured to fit into a predetermined space, such as a glove compartment of a car dashboard or the like.

The secondary device may adopt a substantially flat form factor with a core thickness of 2mm or less. Using a material such as one or more amorphous metal sheets, it is possible to have core thickness down to 1mm or less for applications where size and weight is important. See Figure 7a.

In a preferred embodiment, the primary unit may include a pair of conductors having adjacent coplanar windings which have mutually substantially parallel linear sections arranged so as to produce a substantially uniform electromagnetic field extending generally parallel to the plane of the windings but substantially at right angles to the parallel sections.

The windings in this embodiment may be formed in a generally spiral shape, comprising a series of turns having substantially parallel straight sections.

Advantageously, the primary unit may include first and second pairs of conductors which are superimposed in substantially parallel planes with the substantially parallel linear sections of the first pair arranged generally at right angles to the substantially parallel linear sections of the second pair, and further comprising a driving circuit

which is arranged to drive them in such a way as to generate a resultant field which rotates in a plane substantially parallel to the planes of the windings.

According to a fifth aspect of the present invention, there is provided a system for transferring power in a contact-less manner consisting of:

- a primary unit consisting of at least one electrical coil whereby each coil features at least one active area whereby two or more conductors are substantially distributed over this area in such a fashion that it is possible for a secondary device to be placed in proximity to a part of this active area where the net instantaneous current flow in a particular direction is substantially non-zero;
- at least one secondary device consisting of conductors wound around a high permeability core in such a fashion that it is possible for it to be placed in proximity to an area of the surface of the primary unit where the net instantaneous current flow is substantially non-zero;

whereby the at least one secondary device is capable of receiving power by means of electromagnetic induction when the central axis of the winding is in proximity to the active area of the primary unit, is substantially not perpendicular to the plane of the active area of primary unit and is substantially not parallel to the conductors in the active area of at least one of the coils of the primary unit.

Where the secondary device comprises an inductively rechargeable battery or cell, the battery or cell may have a primary axis and be capable of being recharged by an alternating field flowing in the primary axis of the battery or cell, the battery or cell consisting of:

- an enclosure and external electrical connections similar in dimensions to industry-standard batteries or cells
- an energy-storage means
- an optional flux-concentrating means
- a power-receiving means

a combination of primary conductors where the secondary device can couple flux effectively. Some embodiments of this are shown in Figures 6a to 6e and 9c as component **740**. A feature of an "active area" is a distribution of conductors over a significant area of the primary unit configured such that it is possible for the at least one primary conductor to be driven to achieve an instantaneous net flow of flux in one direction. A primary unit may have more than one active area. One active area is distinct from another active area when flux cannot be effectively coupled by the secondary device (shown in Figure 7a) in any rotation at the boundary.

It is to be understood that the term "coil" used in this patent refers to all conductor configurations which feature an active area as described above. This includes windings of wire or printed tracks or a planes as shown in Figure 8e. The conductors may be made of copper, gold, alloys or any other appropriate material.

This patent refers to the rotation of a secondary device in several places. It is to be clarified here that if a secondary device is rotated, the axis of rotation being referred to is the one perpendicular to the plane of the active area.

This radical change in design overcomes a number of drawbacks of conventional systems. The benefits of the proposed invention include:

- No need for accurate alignment: The secondary device can be placed anywhere on the active area of the primary unit;

- Uniform coupling: In the proposed invention, the coupling between the primary unit and secondary device is much more uniform over the active area compared to a conventional primary and secondary coil. In a conventional large coil system (see Figure 2a), the field strength dips to a minimum at the centre of the coil, in the plane of the coil. This implies that if sufficient power is to be effectively transferred at the centre, the field strength at the minimum has to be above a certain threshold. The field strength at the

maximum will then be excessively higher than the required threshold and this may cause undesirable effects.

- Universality: a number of different secondary devices can be placed anywhere on the primary unit to receive power simultaneously;

- Increased coupling coefficiency: Optional high permeability magnetic material present in the secondary device increases the induced flux significantly by offering a low reluctance path. This can significantly increase the power transfer.

- Desirable form factor for secondary device: The geometry of the system allows thin sheets of magnetic material (such as amorphous metal ribbons) to be used. This means that secondary devices can have the form factor of a thin sheet, making it suitable to be incorporated at the back of mobile phones and other electronic devices. If magnetic material was to be used in the centre of conventional coils, it is likely to increase the bulkiness of whole system.

- Minimised field leakage: When one or more secondary devices are present in the active area of the primary unit, it is possible to use magnetic material in such a way that more than half of the magnetic circuit is low reluctance magnetic material (see figure 4e). This means that more flux flows for a given magneto-motive force (mmf). As the induced voltage is proportional to the rate of change of flux linked, this will increase the power transfer to the secondary device. The fewer and shorter the air gaps are in the magnetic circuit, the less the field will fringe, the closer the flux is kept to the surface of the primary unit and hence leakage is minimized.

- Cost effectiveness: Unlike the multiple-coil design, this solution requires a much simpler control system and fewer components.

- Free axial rotation of secondary device: If the secondary device is thin or optionally even cylindrical (see Figure 10), it may be constructed such that it continues to couple well to the flux regardless of its rotation about its longest axis. This may in particular be an advantage if the secondary device is a battery cell fitted within another device, when its axial rotation may be difficult to control.

The primary unit typically consists of the following components. (See Figure 5)

- Power supply: This power supply converts mains voltage into a lower voltage dc supply. This is typically a conventional transformer or a switch-mode power supply;

- Control unit: The control unit serves the function of maintaining the resonance of the circuit given that the inductance of the magnetic component changes with the presence of secondary devices. To enable this function, the control unit may be coupled to a sensing unit which feeds back the current status of the circuit. It may also be coupled to a library of capacitors which may be switched in and out as required. If the magnetic unit requires more than one driving circuit, the control unit may also coordinate the parameters such as the phase difference or on/off times of different driving circuits such that the desired effect is achieved. It is also possible for the Q (quality factor) of the system to be designed to function over a range of inductances such that a need the above control system is eliminated;

- Driving circuit: The driving unit is controlled by the control unit and drives a changing current through the magnetic unit or a component of the magnetic unit. More than one driving circuit may be present depending on the number of independent components in the magnetic unit;

- Magnetic unit: The magnetic unit uses current supplied from the driving circuits to generate magnetic fields of pre-defined shapes and intensities. The

exact configuration of the magnetic unit defines the shape and intensity of the field generated. The magnetic unit is likely to consist of magnetic material to act as flux guides and also one or more independently driven components (windings), together forming the active area. A number of embodiment designs are possible and this is shown in Figures 6.

- Sensing unit: The sensing unit retrieves and sends relevant data to the control unit for interpretation.

The secondary device typically consists of the following components, as shown in Figure 5.

- Magnetic unit: the magnetic unit converts the energy stored in the magnetic field generated by the primary unit back into electrical energy. This is typically implemented by means of a winding wound around a highly permeable magnetic core. The largest dimension of the core typically coincides with the central axis of the winding.

- Conversion unit: the conversion unit converts the fluctuating current received from the magnetic unit into a form that is useful to the device that it is coupled to. For example, the conversion unit may convert the fluctuating current into an unregulated dc supply by means of a full-wave bridge rectifier and smoothing capacitor. In other cases, the conversion unit may be coupled to a heating element or a battery charger. There is also typically a capacitor present either in parallel or in series with the magnetic unit to form a resonant circuit at the operating frequency of the primary unit.

In typical operation, one or more secondary devices are placed on top of the active area of the primary unit. The flux flows through the at least one conductor and/or core of the secondary devices present and current is induced. Depending on the configuration of the primary magnetic unit, the rotation of the secondary device may affect the amount of flux coupled.

The primary unit

The primary unit may exist in many different forms, for example:

- As a flat platform which can sit on top of tables and other flat surfaces;
- Built in to furniture such as desks , tables, counters, chairs such that the primary unit may not be visible;
- As part of an enclosure such as a drawer, a box, a glove compartment of a car, the container of power tools;
- As a flat platform which can be attached to a wall and used vertically;

The primary unit may be powered from different sources, for example:

- A mains AC power outlet
- A vehicle lighter socket
- Batteries
- Fuel Cells
- Solar Panel
- Human power

The primary unit may be small enough such that only one secondary device may be accommodated within the active area, or may be large enough to accommodate many secondary devices simultaneously.

The magnetic unit of the primary unit may be driven at mains frequency (50Hz or 60Hz) or at some higher frequency.

The sensing unit of the primary unit may sense the presence of secondary devices, the number of secondary devices present and even the presence of other magnetic material which is not part of a secondary device. This information may be used to control the current being delivered to the magnetic unit of the primary unit.

The primary unit and/or the secondary device may be substantially waterproof or explosion proof.

The primary unit and/or the secondary device may be hermetically sealed to standards such as IP66.

The primary unit may incorporate visual indicators (for example, but not limited to, light emitting devices, such as light emitting diodes, electrophosphorescent displays, light emitting polymers, or light reflecting devices, such as liquid crystal displays or MITs electronic paper) to indicate the current state of the primary unit, the presence of secondary devices or the number of secondary devices present or any combination of the above.

The primary conductor

The primary conductor as referred to in this invention includes all configurations of conductors where:

- The conductors are substantially distributed in the plane and;
- Substantial areas of the plane exist where there is a non-zero net instantaneous current flow. These are areas on which, given the correct orientation, the secondary devices will couple effectively and receive power. (See Figure 6)
- The conductors are capable of generating an electromagnetic field where the field lines are substantially parallel to a substantial area of the plane.

Figure 6 illustrates some possibilities for such a primary conductor. Although most of the configurations are in fact coil windings, it is to be appreciated that the same effect can also be achieved with conductor planes which are not typically considered to be coils (See Figure 6e). These drawings are typical examples and are non-exhaustive. These conductors or coils may be used in combination such that the secondary device can couple effectively in all rotations whilst on the active area of the primary unit.

Magnetic Material

It is possible to use magnetic materials in the primary unit to enhance performance.

- Magnetic material may be placed below the active area such that there is also a low reluctance path on the underside of the conductors for the flux to complete its path. According to theory, an analogy can be drawn between magnetic circuits and electrical circuits. Voltage is analogous to magneto-motive force (mmf), resistance is analogous to reluctance and current is analogous to flux. From this, it can be seen that for a given mmf, flux flow will increase if the reluctance of the path is decreased. By providing magnetic material to the underside of the active area, we are essentially decreasing the reluctance of the magnetic circuit. This substantially increases the flux linked by the secondary device and ultimately increases the power transferred. Figure 4e illustrates a sheet of magnetic material placed underneath the active area and the resulting magnetic circuit.

- Magnetic material may also be placed above the active area and below the secondary devices to act as a flux guide. This flux guide performs two functions: Firstly, it decreases the reluctance of the whole magnetic circuit is further decreased allowing more flux will flow. Secondly, it provides a low reluctance path along the top surface of the active area so the flux lines will flow through these flux guides in favour of flowing through the air. Hence this has the effect of containing the field close to the surface of the primary unit instead of in the air. The magnetic material used for flux guides may be strategically chosen to have different magnetic properties to the magnetic core (where provided) of the secondary device. For example, a material with lower permeability and higher saturation may be chosen. High saturation means that the material can carry more flux and the lower permeability means that when a secondary device is in proximity, a significant amount of flux would then choose to travel through the secondary device in favour of the flux guide. (See Figure 8)

- In some primary magnetic unit configurations, there may be conductors present that do not form part of the active power transfer area, such as the component marked **745** in Figure 6a and 6b. In such cases, one may wish to use magnetic material to shield the effects of these conductors.

- Examples of some materials which may be used include but is not limited to: amorphous metal (metallic glass alloys such as MetGlas™), mesh of wires made of magnetic material, steel, ferrite cores, mumetal.

The Secondary device

The secondary device may take a variety of shapes and forms. Generally, in order for good flux linkage, a central axis of the conductor (for example, a coil winding) should be substantially non-perpendicular to the active area.

- The secondary device may be in the shape of a flattened winding. (See Figure 7a) The magnetic core inside can consist of sheets of magnetic material such as amorphous metals. This geometry allows the secondary device to be incorporated at the back of electronic devices such as mobile phones, personal digital assistants and laptops without adding bulk to the device.
- The secondary device may be in the shape of a long cylinder. A long cylindrical core could be wound with conductors (See Figure 7b).
- The secondary device may be a standard-sized (AA, AAA, C, D) or other sized (e.g. dedicated/customised for particular applications) rechargeable battery cell with for example magnetic material wrapped around the cylinder and windings around the cylindrical body.
- The secondary device may be a combination of two or more of the above. The above embodiments may even be combined with a conventional coil

The following non-exhaustive list illustrates some examples of objects that can be coupled to a secondary device to receive power. Possibilities are not limited to those described below:

- A mobile communication device, for example a radio, mobile telephone or walkie-talkie;
- A portable computing device, for example a personal digital assistant or palmtop or laptop computer;
- Portable entertainment devices, for example a music player, game console or toy;
- Personal care items, for example a toothbrush, shaver, hair curler, hair rollers;
- A portable imaging device, for example video recorder or camera;
- Containers of contents that may require heating, for example coffee mugs, plates, cooking pots, nail-polish and cosmetic containers;
- Consumer devices, for example torches, clocks and fans;
- A battery-pack for insertion into any of the above;
- A standard-sized battery cell;

In the case of unintelligent secondary devices such as a battery cell, some sophisticated charge-control means may also be necessary to meter inductive power to the cell and to deal with situations where multiple cells in a device have different charge states. Furthermore, it becomes more important for the primary unit to be able to indicate a "charged" condition, since the secondary cell or battery may not be easily visible when located inside another electrical device.

A possible system incorporating an inductively rechargeable battery or cell is shown in Figure 10. In addition to the freedom to place the battery 920 freely in (X,Y) and optionally rotate it in rZ, relative to the primary unit 910, the battery can also be rotated along its axis rA while continuing to receive power.

When a user inserts a battery into a portable device, it is not easy to ensure that it has any given axial rotation. Therefore, embodiments of the present invention are highly advantageous because they can ensure that the battery can receive power while in any random orientation about rA.

The battery or cell may include a flux concentrating means that may be arranged in a variety of ways:

1. As shown in Figure 11a, a cell 930 may be wrapped in a cylinder of flux-concentrating material 931, around which is wrapped a coil of wire 932.
    a. The cylinder may be long or short relative to the length of the cell.
2. As shown in Figure 11b, a cell 930 may have a portion of flux-concentrating material 931 on its surface, around which is wrapped a coil of wire 932.
    a. The portion may be conformed to the surface of the cell, or embedded within it.
    b. Its area may be large or small relative to the circumference of the cell, and long or short relative to the length of the cell.
3. As shown in Figure 11c, a cell 930 may contain a portion of flux-concentrating material 931 within it, around which is wrapped a coil of wire 932.
    a. The portion may be substantially flat, cylindrical, rod-like, or any other shape.
    b. Its width may be large or small relative to the diameter of the cell
    c. Its length may be large or small relative to the length of the cell

In any of these cases, the flux-concentrator may be a functional part of the battery enclosure (for example, an outer zinc electrode) or the battery itself (for example, an inner electrode).

Issues relating to charging e.g. AA cells in-situ within an appliance include:

- Terminal voltage could be higher than normal.
- Cells in series may behave strangely, particularly in situations where some cells are charged, others not.
- Having to provide enough power to run the device and charge the cell.
- If fast-charging is effected incorrectly, the cells may explode, so raising product liability issues.

Accordingly, some sophisticated charge-control means to meter inductive power to the appliance and the cell is advantageously provided. Furthermore, it becomes more important for the primary unit to be able to indicate a "charged" condition, since the secondary cell or battery may not be easily visible when located inside an electrical device.

A cell or battery enabled in this fashion may be charged whilst fitted in another device, by placing the device onto the primary unit, or whilst outside the device by placing the cell or battery directly onto the primary unit.

Batteries enabled in this fashion may be arranged in packs of cells as in typical devices (e.g. end-to-end or side-by-side), allowing a single pack to replace a set of cells.

Alternatively, the secondary device may consist of a flat "adapter" which fits over the batteries in a device, with thin electrodes which force down between the battery electrodes and the device contacts.

Rotating magnetic dipole

In the coils such as those in Figure 6, 9a and 9b, the secondary devices will generally only couple effectively when the windings are placed substantially parallel to the direction of net current flow in the primary conductor as shown by the arrow **1**. In some applications, one might require a primary unit which will transfer power effectively to secondary devices regardless of their rotation as long as:

- the central axis of the secondary conductor is not perpendicular to the plane and;
- the secondary device is in close proximity to the primary unit

To enable this, it is possible to have two coils, for example one positioned on top of the other or one woven into or otherwise associated with the other, the second coil capable of generating a net current flow substantially perpendicular to the direction of the first coil at any point in the active area of the primary unit. These two coils

may be driven alternately such that each is activated for a certain period of time. Another possibility is to drive the two coils in quadrature such that a rotating magnetic dipole is generated in the plane. This is illustrated in Figure 9. This is also possible with other combinations of coil configurations.

Resonant circuits

It is known in the art to drive coils using parallel or series resonant circuits. In series resonant circuits for example, the impedance of the coil and the capacitor are equal and opposite at resonance, hence the total impedance of the circuit is minimised and a maximum current flows through the primary coil. The secondary device is typically also tuned to the operating frequency to maximise the induced voltage or current.

In some systems like the electric toothbrush, it is common to have a circuit which is detuned when the secondary device is not present and tuned when the secondary device is in place. The magnetic material present in the secondary device shifts the self-inductance of the primary unit and brings the circuit into resonance. In other systems like passive radio tags, there is no magnetic material in the secondary device and hence does not affect the resonant frequency of the system. These tags are also typically small and used far from the primary unit such that even if magnetic material is present, the inductance of the primary is not significantly changed.

In the proposed system, this is not the case:

- High permeability magnetic material may be present in the secondary device and is used in close proximity to the primary unit;
- One or more secondary devices may be brought in close proximity to the primary unit simultaneously;

This has the effect of shifting the inductance of the primary significantly and also to different levels depending on the number of secondary devices present on the pad. When the inductance of the primary unit is shifted, the capacitance required for the

circuit to resonant at a particular frequency also changes. There are three methods for keeping the circuit at resonance:

- By means of a control system to dynamically change the operating frequency;
- By means of a control system to dynamically change the capacitance such that resonance is achieved at the predefined frequency; .
- By means of a low Q system where the system remains in resonance over a range of inductances

The problem with changing the operating frequency is that the secondary devices are typically configured to resonate at a predefined frequency. If the operating frequency changes, the secondary device would be detuned. To overcome this problem, we can change the capacitance instead of the operating frequency. The secondary devices can be designed such that each additional device placed in proximity to the primary unit will shift the inductance to a quantised level such that an appropriate capacitor can be switched in to make the circuit resonate at a predetermined frequency. Because of this shift in resonant frequency, the number of devices on the pad can be detected and the pad can also sense when something is brought near or taken away from the pad. If a magnetically permeable object other than a valid secondary device is placed in the vicinity of the pad, it is unlikely to shift the system to the predefined quantised level. In such circumstances, the system could automatically detune and reduce the current flowing into the coil.

For a better understanding of the present invention and to show how it may be carried into effect, reference shall now be made, by way of example only, to the accompanying drawings, in which:

FIGURE 1 shows the magnetic design of typical prior art contact-less power transfer systems which require accurate alignment of the primary unit and secondary device;

FIGURE 2a shows the magnetic design of another typical prior art contact-less power transfer system which involves a large coil in the primary unit;

FIGURE 2b shows the non-uniform field distribution inside the large coil at 5mm distance from the plane of the coil, exhibiting a minimum in the centre;

FIGURE 3 shows a multiple-coil system where each coil is independently driven such that a localised field can be generated.

FIGURE 4a shows an embodiment of the proposed system which demonstrates a substantial departure from prior art with no secondary devices present;

FIGURE 4b shows an embodiment of the proposed system with two secondary devices present;

FIGURE 4c shows a cross section of the active area of the primary unit and the contour lines of the magnetic flux density generated by the conductors.

FIGURE 4e shows the magnetic circuit for this particular embodiment of the proposed invention;

FIGURE 5 shows a schematic drawing of an embodiment of the primary unit and the secondary device;

FIGURE 6a, 6b, 6c, 6d, 6e and 6f show some alternative embodiment designs for the magnetic unit or a component of the magnetic unit of the primary unit;

FIGURES 7a and 7b show some embodiment designs for the magnetic unit of the secondary device;

FIGURES 8 shows the effect of flux guides (the thickness of the flux guide has been exaggerated for clarity);

FIGURE 8a shows that without flux guides, the field tends to fringe into the air directly above the active area;

FIGURE 8b shows the direction of current flow in the conductors in this particular embodiment;

FIGURE 8c shows that the flux is contained within the flux guides when magnetic material is placed on top of the active area;

FIGURE 8d shows a secondary device on top of the primary unit;

FIGURE 8e shows a cross section of the primary unit without any secondary devices;

FIGURE 8f shows a cross section of the primary unit with a secondary device on top and demonstrates the effect of using a secondary core with higher permeability than the flux guide.

FIGURE 9a shows a particular coil arrangement with a net instantaneous current flow shown by the direction of the arrow;

FIGURE 9b shows a similar coil arrangement to FIGURE 9a except rotated by 90 degrees;

FIGURE 9c shows the active area of the primary unit if the coil of FIGURE 9a is placed on top of FIGURE 9b. If the coil in FIGURE 9a is driven in quadrature to FIGURE 9b, the effect is a rotating magnetic dipole shown here.

FIGURE 10 shows the case where the secondary device has an axial degree of rotation.

FIGURE 11 shows various arrangements of secondary devices with axial degrees of rotation.

FIGURE 12a and FIGURE 12b show another embodiment of the type of coil arrangement shown in FIGURE 9a and FIGURE 9b.

FIGURE 13 shows a simple embodiment of driving unit electronics.

Referring firstly to Figure 1, there is shown two examples of prior art contact-less power transfer systems which both require accurate alignment of a primary unit and a secondary device. This embodiment is typically used in toothbrush or mobile phone chargers.

Figure 1a shows a primary magnetic unit **100** and a secondary magnetic unit **200**. On the primary side, a coil **110** is wound around a magnetic core **120** such as ferrite. Similarly, the secondary side consists of a coil **210** wound around another magnetic core **220**. In operation, an alternating current flows in to the primary coil **110** and generates lines of flux **1**. When a secondary magnetic unit **200** is placed such that it is axially aligned with the primary magnetic unit **100**, the flux **1** will couple from the primary into the secondary, inducing a voltage across the secondary coil **210**.

Figure 1b shows a split transformer. The primary magnetic unit **300** consists of a U-shaped core **320** with a coil **310** wound around it. When alternating current flows into the primary coil **310**, changing lines of flux is generated **1**. The secondary magnetic unit **400** consists of a second U-shaped core **420** with another coil **410** wound around it. When the secondary magnetic unit **400** is placed on the primary magnetic unit **300** such that the arms of the two U-shaped cores are in alignment, the flux will couple effectively into the core of the secondary **420** and induce voltage across the secondary coil **410**.

Figure 2a is another embodiment of prior art inductive systems typically used in powering radio frequency passive tags. The primary typically consists of a coil **510** covering a large area. Multiple secondary devices **520** will have voltage induced in it when they are within the area encircled by the primary coil **510**. This system does not require the secondary coil **520** to be accurate aligned with the primary coil **510**.

Figure 2b shows a graph of the magnitude of magnetic flux intensity across the area encircled by the primary coil **510** at 5mm above the plane of the primary coil. It shows a non-uniform field, which exhibits a minimum **530** at the centre of the primary coil **510**.

Figure 3 is another embodiment of prior art inductive system where by a multiple coil array is used. The primary magnetic unit **600** consists of an array of coils including **611, 612, 613**. The secondary magnetic unit **700** may consist of a coil **710**. When the secondary magnetic unit **700** is in proximity to some coils in the primary magnetic unit **600**, the coils **611, 612** are activated while other coils such as **613** remains inactive. The activated coils **611, 612** generate flux, some of which will couple into the secondary magnetic unit **700.**

Figure 4 shows an embodiment of the proposed invention. Figure 4a shows a primary coil **710** wound or printed in such a fashion that there is a net instantaneous current flow within the active area **740.** For example, if a dc current flows through the primary coil **710,** the conductors in the active area **740** would all have current flowing in the same direction. Current flowing through the primary coil **710** generates flux **1**. A layer of magnetic material **730** is present beneath the active area to provide a return path for the flux. Figure 4b shows the same primary magnetic unit as shown in Figure 4a with two secondary devices **800** present. When the secondary devices **800** are placed in the correct orientation on top of the active area **740** of the primary magnetic unit, the flux **1** would flow through the magnetic core of the secondary devices **800** instead of flowing through the air. The flux **1** flowing through the secondary core would hence induce current in the secondary coil.

Figure 4c shows some contour lines for the flux density of the magnetic field generated by the conductors **711** in the active area **740** of the primary magnetic unit **700**. There is a layer of magnetic material **730** beneath the conductors to provide a low impedance return path for the flux.

Figure 4e shows a cross-section of the active area **740** of the primary magnetic unit

700. A possible path for the magnetic circuit is shown. The magnetic material **730** provides a low reluctance path for the circuit and also the magnetic core **820** of the secondary magnetic device **800** also provides a low reluctance path. This minimizes the distance the flux has to travel through the air and hence minimizes leakage.

Figure 5 shows a schematic drawing of an embodiment of the whole system of the proposed invention. In this embodiment, the primary unit consists of a power supply **760**, a control unit **770**, a sensing unit **780** and a magnetic unit **700**. The power supply **760** converts the mains (or other sources of power) into a dc supply at an appropriate voltage for the system. The control unit **770** controls the driving unit **790** which drives the magnetic unit **700**. In this embodiment, the magnetic unit consists of two independently driven components, coil 1 and coil2, arranged such that the conductors in the active area of coil 1 would be perpendicular to the conductors in the active area of coil 2. When the primary unit is activated, the control unit causes a 90-degree phase shift between the alternating current that flows through coil 1 and coil 2. This creates a rotating magnetic dipole on the surface of the primary magnetic unit **700** such that a secondary device would be able to receive power regardless of its rotational orientation (See Figure 9). In standby mode where no secondary devices are present, the primary is detuned and current flow into the magnetic unit **700** is minimised. When a secondary device is placed on top of the active area of the primary unit, the inductance of the primary magnetic unit **700** is changed. This brings the primary circuit into resonance and the current flow is maximised. When there are two secondary devices present on the primary unit, the inductance is changed to yet another level and the primary circuit is again detuned. At this point, the control unit **770** uses feedback from the sensing unit **780** to switch another capacitor into the circuit such it is tuned again and current flow is maximised. In this embodiment, the secondary devices are of a standard size and a maximum of six standard-sized devices can receive power from the primary unit simultaneously. Due to the standard-sizes of the secondary devices, the change in inductance due to the change in secondary devices in proximity is quantized to a number of predefined levels such that only a maximum of 6 capacitances is required to keep the system operating at resonance.

Figures 6a to 6f show a number of different embodiments for the coil component of the primary magnetic unit. These embodiments may be implemented as the only coil component of the primary magnetic unit, in which case the rotation of the secondary device is important to the power transfer. These embodiments may also be implemented in combination, not excluding embodiments which are not illustrated here. For example, two coils illustrated in Figure 6a may be placed at 90 degrees to each other to form a single magnetic unit. In Figures 6a to 6e, the active area **740** consists of a series of conductors with net current generally flowing in the same direction. In certain configurations, such as Figure 6c, there is no substantial linkage when the secondary device is placed directly over the centre of the coil and hence power is not transferred. In Figure 6d, there is no substantial linkage when the secondary device is positioned in the gap between the two active areas **740**.

Figure 6f shows a specific coil configuration for the primary unit adapted to generate electromagnetic field lines substantially parallel to a surface of the primary unit within the active area **740**. Two primary windings **710**, one on either side of the active area **740**, are formed about opposing arms of a generally rectangular flux guide **750** made out of a magnetic material, the primary windings **710** generating opposing electromagnetic fields. The flux guide **750** contains the electromagnetic fields and creates a magnetic dipole across the active area **740** in the direction of the arrows indicated on the Figure. When a secondary device is placed in the active area **740** in a predetermined orientation, a low reluctance path is created and flux flows through the secondary device, causing effective coupling and power transfer.

Figure 7a and 7b are embodiments of the proposed secondary devices. A winding **810** is wound around a magnetic core **820**. Two of these may be combined in a single secondary device, at right angles for example, such that the secondary device is able to effectively couple with the primary unit at all rotations. These may also be combined with standard coils, as the ones shown in Figure 2a **520** to eliminate dead spots.

Figure 8 shows the effect of flux guides **750** positioned on top of the active area. The thickness of the material has been exaggerated for the sake of clarity but in reality would be in the order of millimetres thick. The flux guides **750** will minimize leakage and contain the flux at the expense of reducing the amount of flux coupled to the secondary device. In Figure 8a, a primary magnetic unit is shown without flux guides **750**. The field will tend to fringe into the air directly above the active area. With flux guides **750,** as shown in Figure 8b to 8f, the flux is contained within the plane of the material and leakage is minimised. In Figure 8e, when there is no secondary device **800** on top, the flux remains in the flux guide **750**. In Figure 8f, when a secondary device **800** is present with a relatively more permeable material as the core, part of the flux will flow via the secondary device. The permeability of the flux guide **750** can be chosen such that it is higher than that of typical metals such as steel. When other materials such as steel, which are not part of secondary devices **800**, are placed on top, most of the flux will remain in the flux guide **750** instead of travelling through the object. The flux guide **750** may not be a continuous layer of magnetic material but may have small air gaps in them to encourage more flux flow into the secondary device **800** when it is present.

Figure 9 shows an embodiment of a primary unit whereby more than one coil is used. Figure 9a shows a coil **710** with an active area **740** with current flow parallel to the direction of the arrow **1**. Figure 9b shows a similar coil arranged at 90 degrees to the one in Figure 9a. When these two coils are placed on top of each other such that the active area **740** overlaps, the active area would look like the illustration in Figure 9c. Such an embodiment would allow the secondary device to be at any rotation on top of the primary unit and couple effectively.

Figure 10 shows an embodiment where the secondary device has an axial degree of rotation, for example where it is, or it is embedded within, a battery cell. In this embodiment the secondary device may be constructed such that it couples to the primary flux when in any axial rotation (rA) relative to the primary unit **(910)**, as well as having the same degrees of freedom described above (i.e. translational (X,Y) and optionally rotational perpendicular to the plane of the primary (rZ).

Figure 11a shows one arrangement where a rechargeable battery cell **930** is wrapped with an optional cylinder of flux-concentrating material **931** which is itself wound with copper wire **932**. The cylinder may be long or short relative to the length of the cell.

Figure 11b shows another arrangement where the flux-concentrating material **931** covers only part of the surface of the cell **930**, and has copper wire **932** wrapped around it (but not the cell). The material and wire may be conformed to the surface of the cell. Their area may be large or small relative to the circumference of the cell, and long or short relative to the length of the cell.

Figure 11c shows another arrangement where the flux-concentrating material **931** is embedded within the cell **930** and has copper wire **932** wrapped around it. The material may be substantially flat, cylindrical, rod-like, or any other shape, its width may be large or small relative to the diameter of the cell, and its length may be large or small relative to the length of the cell.

In any case shown in Figures 10 and 11, any flux-concentrating material may also be a functional part of the battery enclosure (for example, an outer zinc electrode) or the battery itself (for example, an inner electrode).

In any case shown in Figures 10 and 11, the power may be stored in a smaller standard cell (e.g. AAA size) fitted within the larger standard cell enclosure (e.g. AA).

Figure 12 shows an embodiment of a primary unit similar to that shown in Figure 9. Figure 12a shows a coil generating a field in a direction horizontal to the page, Figure 12b shows another coil generating a field vertical to the page, and the two coils would be mounted in a substantially coplanar fashion, possibly with one above the other, or even intertwined in some fashion. The wire connections to each coil are shown **940** and the active area is represented by the arrows **941**.

Figure 13 shows a simple embodiment of the Driving Unit (790 of Figure 5). In this embodiment there is no Control Unit. The PIC processor 960 generates two 23.8kHz square waves 90 degrees out of phase with one another. These are amplified by components 961 and driven into two coil components 962, which are the same magnetic units shown in Figure 12a and Figure 12b. Although the driving unit is providing square waves the high resonant "Q" of the magnetic units shapes this into a sinusoidal waveform.

The preferred features of the invention are applicable to all aspects of the invention and may be used in any possible combination.

Throughout the description and claims of this specification, the words "comprise" and "contain" and variations of the words, for example "comprising" and "comprises", mean "including but not limited to", and are not intended to (and do not) exclude other components, integers, moieties, additives or steps.

CLAIMS:

1. A system for transferring power without requiring direct electrical conductive contacts, the system comprising:

i) a primary unit having a substantially laminar surface with at least one electrical conductor that generates an electromagnetic field when a current flows therethrough and having an active area defined within a perimeter of the surface, the at least one conductor being arranged such that electromagnetic field lines generated by the at least one conductor are substantially parallel to the plane of the surface within the active area; and

ii) at least one secondary device including at least one electrical conductor;

wherein the active area of the primary unit has a perimeter large enough to surround the electrical conductor of the at least one secondary device in any orientation thereof substantially parallel to the surface of the primary unit in the active area, such that when the at least one secondary device is placed on or in proximity to the active area in a predetermined orientation, the electromagnetic field induces a current in the at least one conductor of the at least one secondary device.

2. A system as claimed in claim 1, wherein the primary unit includes a plurality of conductors configured so as to be able to generate a magnetic dipole that is switchable between different directions.

3. A system as claimed in claim 2, wherein the plurality of conductors is configured so as to be able to generate a rotating magnetic dipole in or substantially parallel to the laminar surface.

4. A system as claimed in any preceding claim, wherein the at least one conductor is substantially distributed and/or contained within the active area.

5. A system as claimed in any preceding claim, wherein the active area is provided with a substrate of a magnetic material.

6. A system as claimed in any preceding claim, wherein the primary unit includes at least one selectively operable capacitor adapted that a capacitance of a circuit including the at least one conductor and the at least one capacitor may be changed in response to a detected presence of one or more secondary devices.

7. A system as claimed in any preceding claim, wherein the active area is provided with a flux guide having a relative permeability less than that of the core of the at least one secondary device.

8. A system as claimed in any preceding claim, wherein the primary unit includes a power supply.

9. A system as claimed in any preceding claim, wherein the at least one conductor in the secondary device is wound about a core that serves to concentrate flux therein.

10. A system as claimed in claim 9, wherein the core is a magnetically permeable material.

11. A system as claimed in claim 10, wherein the core is an amorphous magnetic material.

12. A system as claimed in any preceding claim, wherein the secondary device comprises an inductively rechargeable battery or cell.

13. A system as claimed in claim 12, wherein the inductively rechargeable battery or cell includes at least one conductor wound about a flux concentrating means.

14. A primary unit for transferring power in a non-conductive manner to at least one secondary device including at least one electrical conductor, the primary unit having a substantially laminar surface with at least one electrical conductor that generates an electromagnetic field when a current flows therethrough and having an active area defined within a perimeter of the surface, the at least one conductor of the primary unit being arranged such that electromagnetic field lines generated by the at least one conductor of the primary unit are substantially parallel to a plane of the surface within the active area, and wherein the active area has a perimeter large enough to surround the conductor of the at least one secondary device in any orientation thereof substantially parallel to the surface of the primary unit in the active area.

15. A primary unit as claimed in claim 14, including a plurality of primary unit conductors configured so as to be able to generate a magnetic dipole that is switchable between different directions.

16. A primary unit as claimed in claim 15, wherein the plurality of primary unit conductors is configured so as to be able to generate a rotating magnetic dipole in or substantially parallel to the laminar surface.

17. A primary unit as claimed in any one of claims 14 to 16, wherein the at least one primary unit conductor is substantially distributed and/or contained within the active area.

18. A primary unit as claimed in any one of claims 14 to 17, wherein the active area is provided with a substrate of a magnetic material.

19. A primary unit as claimed in any one of claims 14 to 18, including at least one selectively operable capacitor adapted that a capacitance of a circuit including the at least one primary unit conductor and the at least one capacitor may be changed in response to a detected presence of one or more secondary devices.

20. A primary unit as claimed in any one of claims 14 to 19, wherein the primary unit includes a power supply.

21. A primary unit as claimed in any one of claims 14 to 20, wherein the active area is provided with a flux guide having a relative permeability less than that of any core that may be provided in the at least one secondary device.

22. A method of transferring power in a non-conductive manner from a primary unit to a secondary device, the primary unit having a substantially laminar surface with at least one electrical conductor that generates an electromagnetic field when a current flows therethrough and having an active area defined within a perimeter of the surface, the at least one conductor being arranged such that electromagnetic field lines generated by the at least one conductor are substantially parallel to the plane of the surface within the active area, and the secondary device having at least one electrical conductor, wherein the active area has a perimeter large enough to surround the conductor of the at least one secondary device in any orientation thereof substantially parallel to the surface of the primary unit within the active area and wherein flux lines of the electromagnetic field link with the conductor of the secondary device when this is placed on or in proximity to the active area.

23. A method according to claim 22, wherein the primary unit includes a plurality of conductors which generate a magnetic dipole that is switchable between different directions.

24. A method according to claim 23, wherein the plurality of conductors generate a rotating magnetic dipole in or substantially parallel to the laminar surface.

25. A method according to any one of claims 22 to 24, wherein the at least one primary unit conductor is substantially distributed and/or contained within the active area.

26. A method according to any one of claims 22 to 25, wherein the active area is provided with a substrate of a magnetic material and wherein the magnetic material completes a magnetic circuit.

27. A method according to any one of claims 22 to 26, wherein the primary unit includes at least one capacitor that is switched in or out such that a capacitance of a circuit including the at least one primary unit conductor and the at least one capacitor may be changed in response to a detected presence of one or more secondary devices.

28. A method according to any one of claims 22 to 27, wherein the active area is provided with a flux guide having a relative permeability less than that of any core that may be provided in the at least one secondary device.

29. A secondary device for use with the system, primary unit or method of any one of the preceding claims, the secondary device including at least one electrical conductor having a substantially flat form factor.

30. A secondary device as claimed in claim 29, wherein the at least one electrical conductor is wound about a core that serves to concentrate flux therein.

31. A secondary device as claimed in claim 30, wherein the core is a magnetically permeable material.

32. A secondary device as claimed in claim 31, wherein the core is an amorphous magnetic material.

33. A secondary device as claimed in any one of claims 29 to 32, wherein the secondary device comprises an inductively rechargeable battery or cell.

34. A secondary device as claimed in claim 30 or any claim depending therefrom, having a core thickness of 2mm or less.

35. A secondary device as claimed in claim 34, having a core thickness of 1mm or less.

36. A secondary device as claimed in any one of claims 29 to 35, wherein the secondary device has a primary axis and is adapted to be rechargeable when in any rotation about its axis.

37. A system as claimed in any one of claims 1 to 13, wherein the primary unit includes a pair of conductors having adjacent coplanar windings which have mutually substantially parallel linear sections arranged so as to produce a substantially uniform electromagnetic field extending generally parallel to the plane of the windings but substantially at right angles to the parallel sections.

38. A system as claimed in claim 37, wherein the windings are formed in a generally spiral shape, comprising a series of turns having substantially parallel straight sections.

39. A system as claimed in claim 37 or 38, wherein the primary unit includes first and second pairs of conductors which are superimposed in substantially parallel planes with the substantially parallel linear sections of the first pair arranged generally at right angles to the substantially parallel linear sections of the second pair, and further comprising a driving circuit which is arranged to drive them in such a way as to generate a resultant field which rotates in a plane substantially parallel to the planes of the windings.

40. A primary unit as claimed in any one of claims 14 to 21, including a pair of conductors having adjacent coplanar windings which have mutually substantially parallel linear sections arranged so as to produce a substantially uniform electromagnetic field extending generally parallel to the plane of the windings but substantially at right angles to the parallel sections.

41. A primary unit as claimed in claim 40, wherein the windings are formed in a generally spiral shape, comprising a series of turns having substantially parallel straight sections.

42. A primary unit as claimed in claim 40 or 41, including first and second pairs of conductors which are superimposed in substantially parallel planes with the substantially parallel linear sections of the first pair arranged generally at right angles to the substantially parallel linear sections of the second pair, and further comprising a driving circuit which is arranged to drive them in such a way as to generate a resultant field which rotates in a plane substantially parallel to the planes of the windings.

43. A system for transferring power, substantially as hereinbefore described with reference to Figures 4 to 13 of the accompanying drawings.

44. A primary unit for transferring power, substantially as hereinbefore described with reference to Figures 4 to 13 of the accompanying drawings.

45. A method of transferring power, substantially as hereinbefore described with reference to Figures 4 to 13 of the accompanying drawings.

46. A secondary device for receiving power, substantially as hereinbefore described with reference to Figures 4 to 13 of the accompanying drawings.

ABSTRACT

IMPROVEMENTS RELATING TO CONTACTLESS POWER TRANSFER

There is disclosed a system and method for transferring power without requiring direct electrical conductive contacts. There is provided a primary unit having a power supply and a substantially laminar surface having at least one conductor that generates an electromagnetic field when a current flows therethrough and having an active area defined within a perimeter of the surface, the at least one conductor being arranged such that electromagnetic field lines generated by the at least one conductor are substantially parallel to the plane of the surface within the active area; and at least one secondary device including at least one conductor that may be wound about a core; wherein the active area has a perimeter large enough to surround the conductor or core of the at least one secondary device in any orientation thereof substantially parallel to the surface of the primary unit in the active area, such that when the at least one secondary device is placed on or in proximity to the active area in a predetermined orientation, the electromagnetic field induces a current in the at least one conductor of the at least one secondary device.

P100245gb2.spc

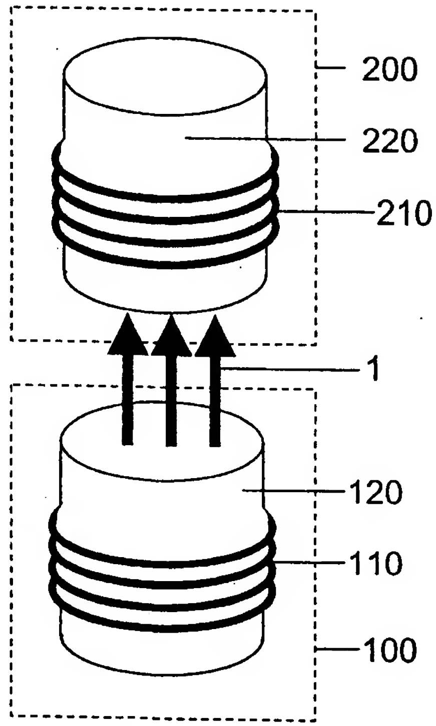

Figure 1a
(Prior Art)

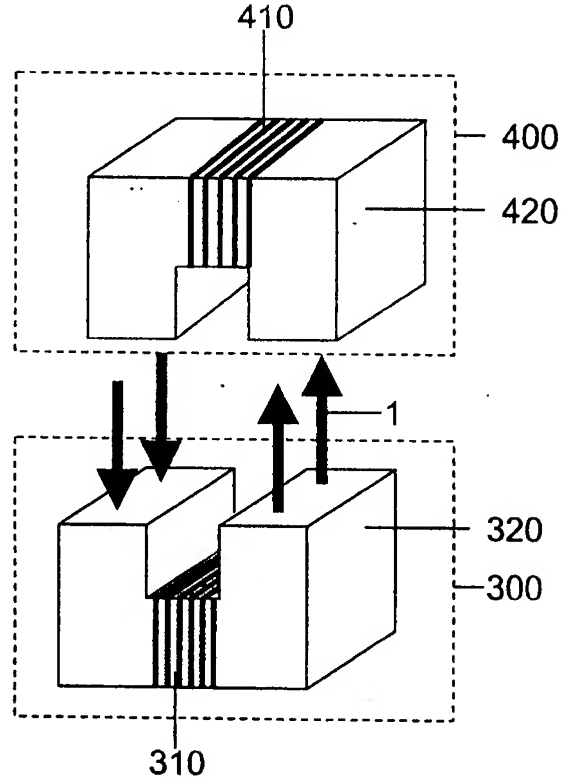

Figure 1b
(Prior Art)

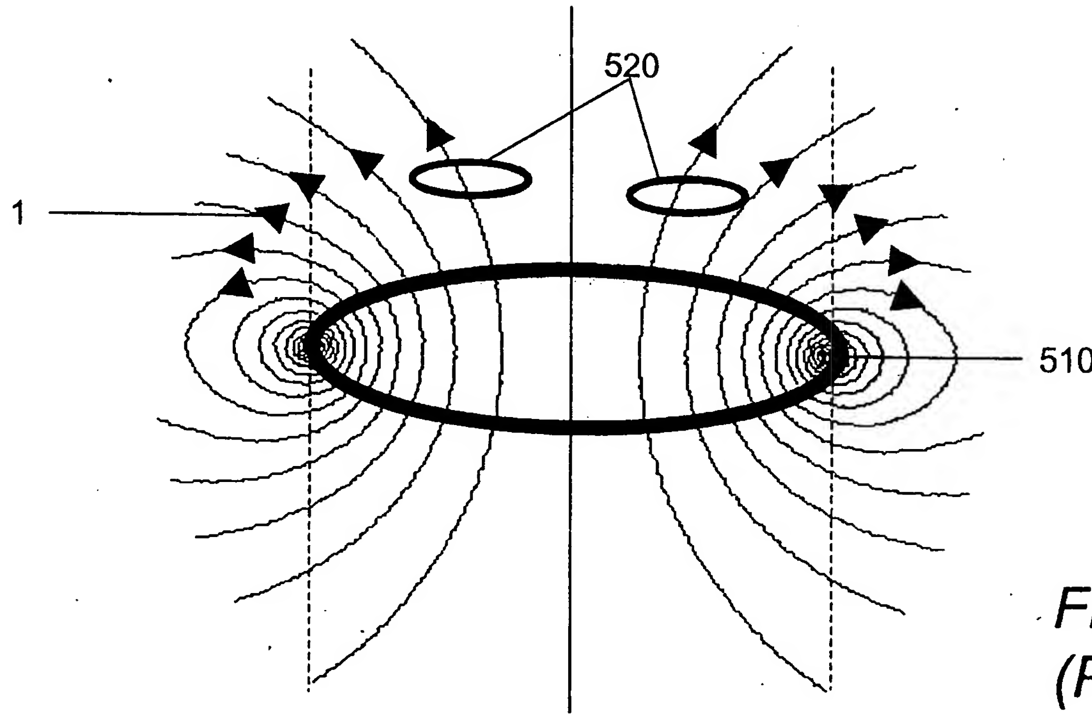

Figure 2a
(Prior Art)

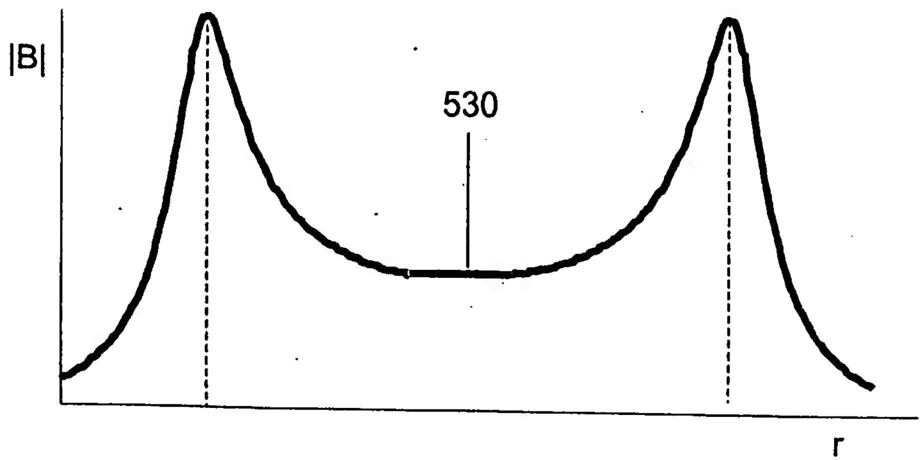

Figure 2b

X =5mm

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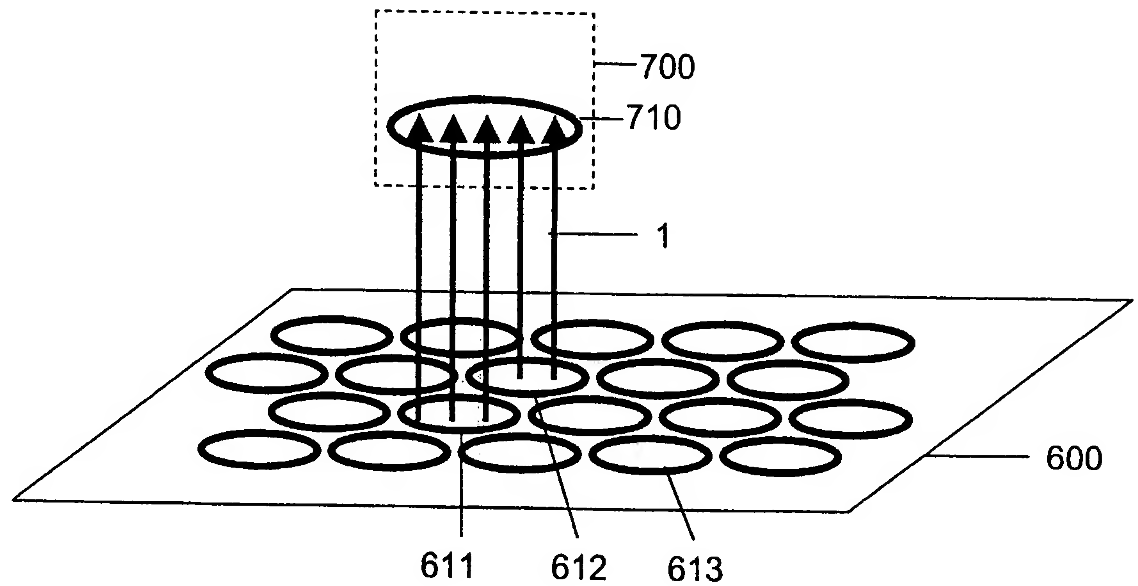

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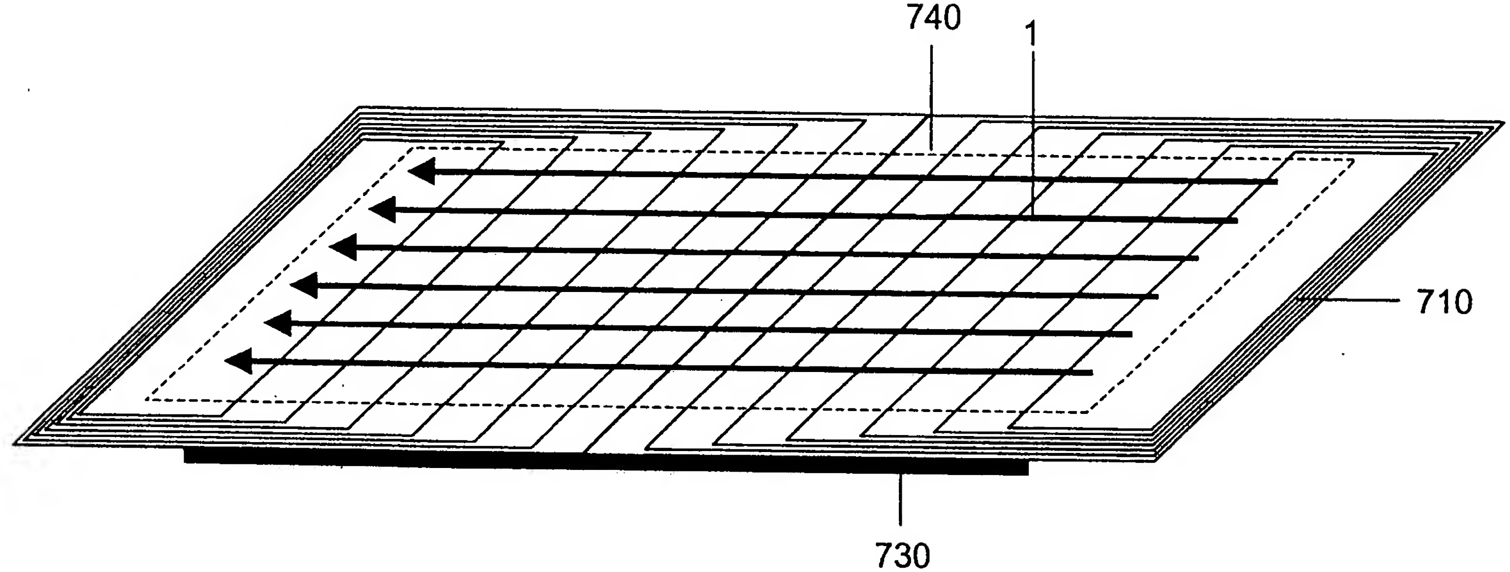

Figure 4a

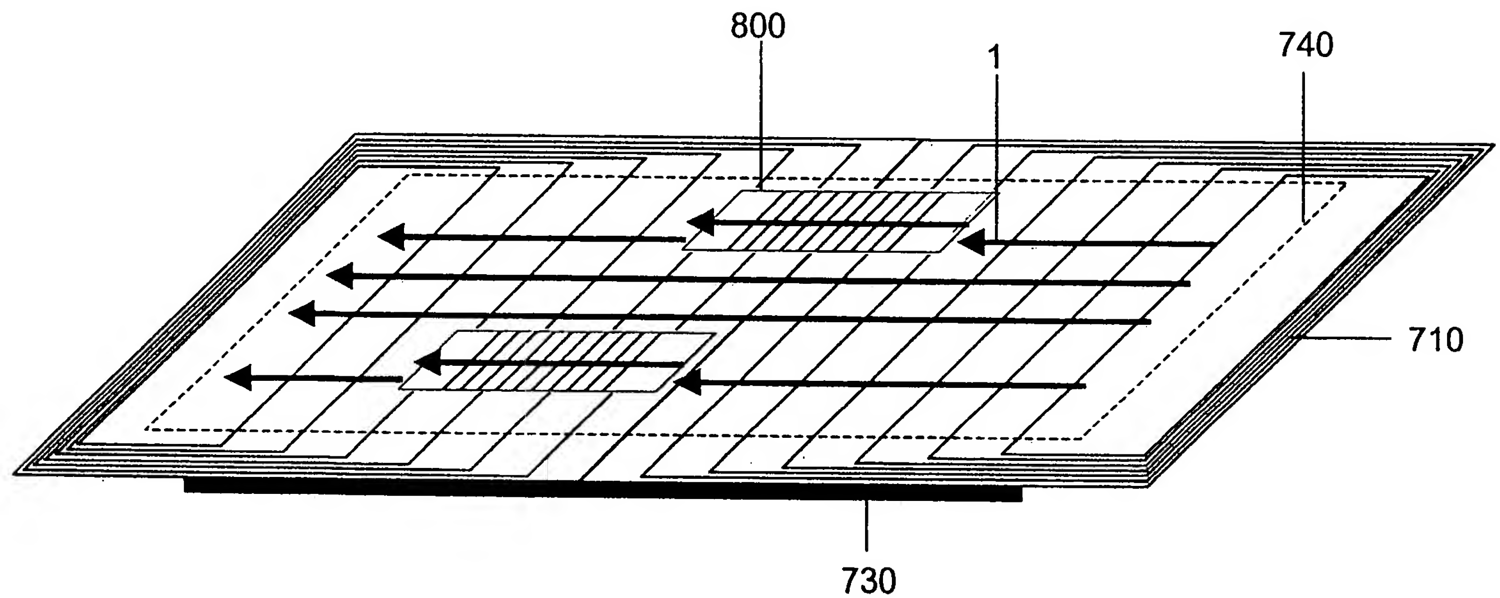

Figure 4b

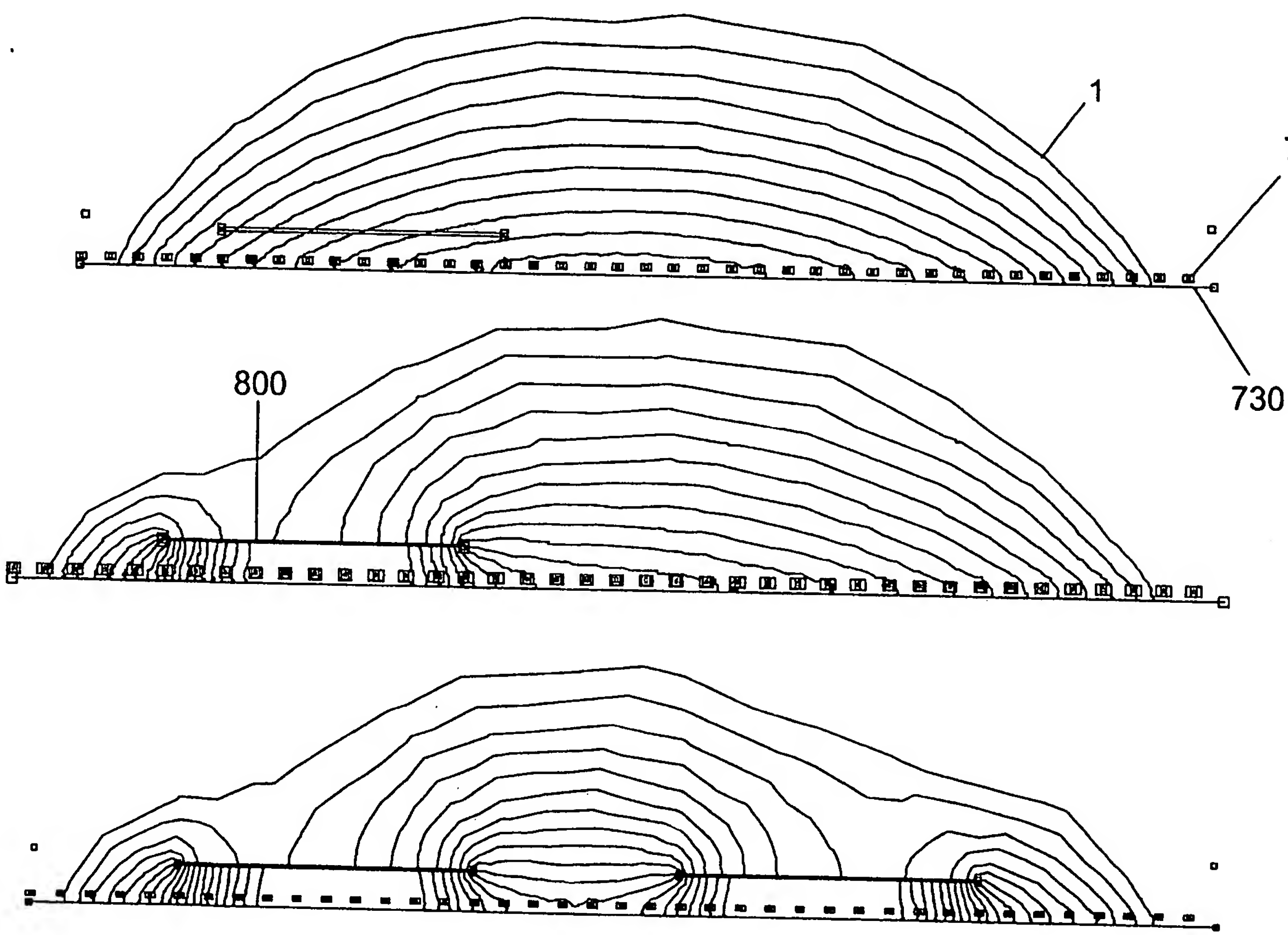

Figure 4c

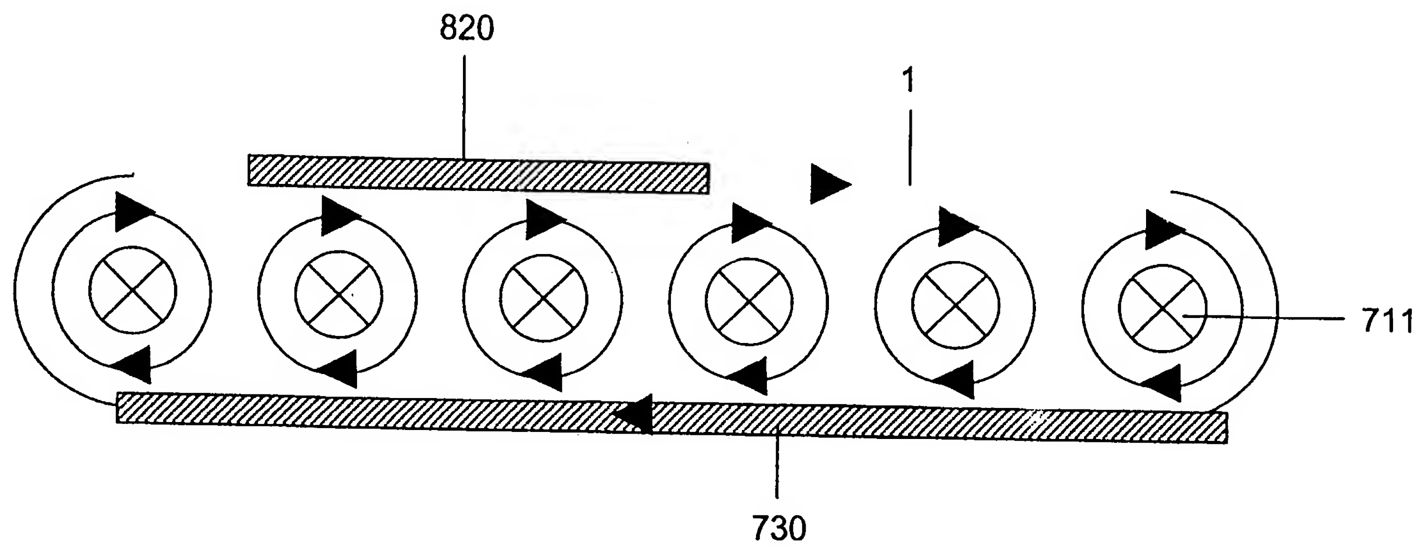

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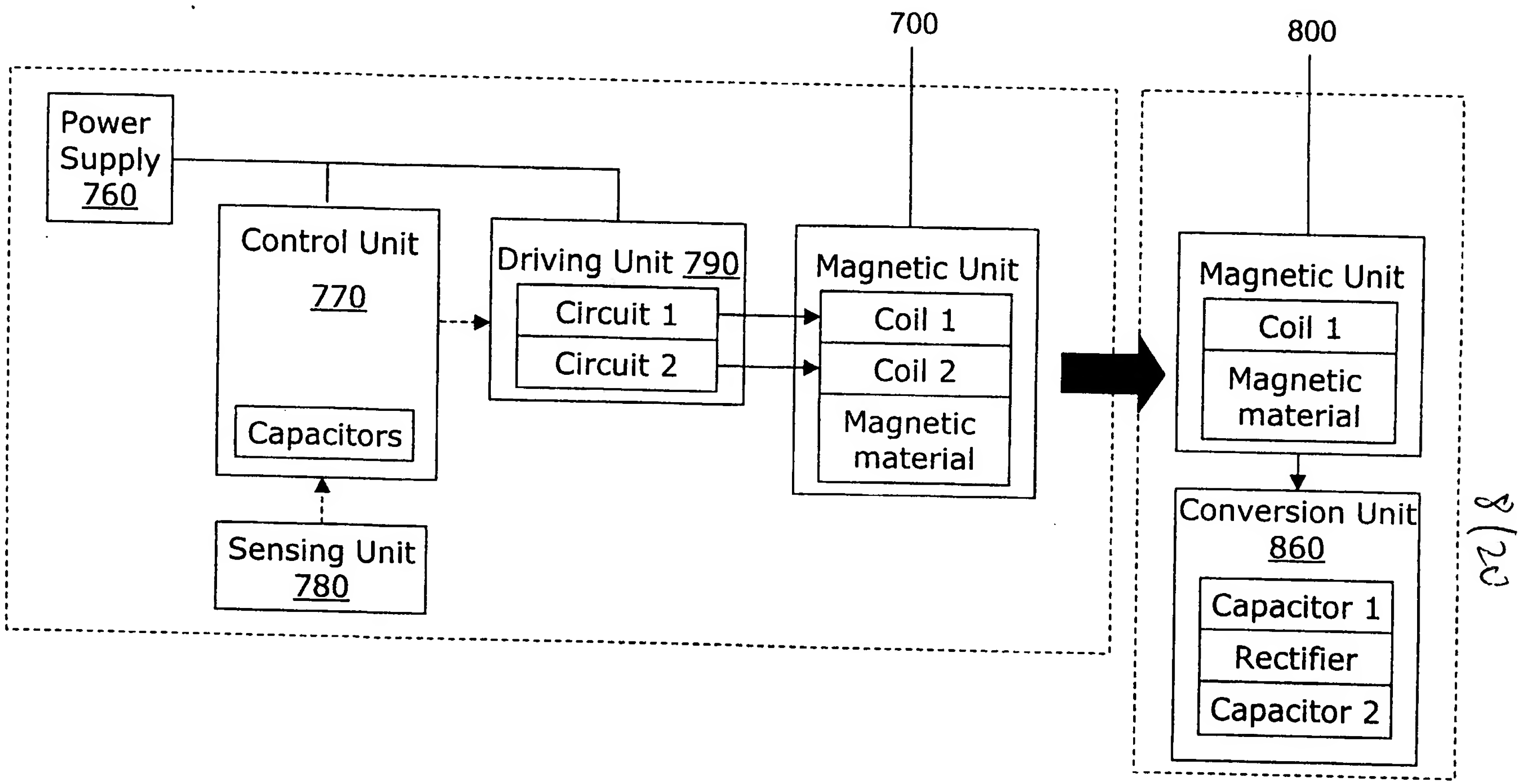
Figure 4e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800
Power Supply 760
Control Unit 770
Capacitors
Sensing Unit 780
Driving Unit 790
Circuit 1
Circuit 2
Magnetic Unit
Coil 1
Coil 2
Magnetic material
Magnetic Unit
Coil 1
Magnetic material
Conversion Unit 860
Capacitor 1
Rectifier
Capacitor 2
8/20

Figure 5

9|20

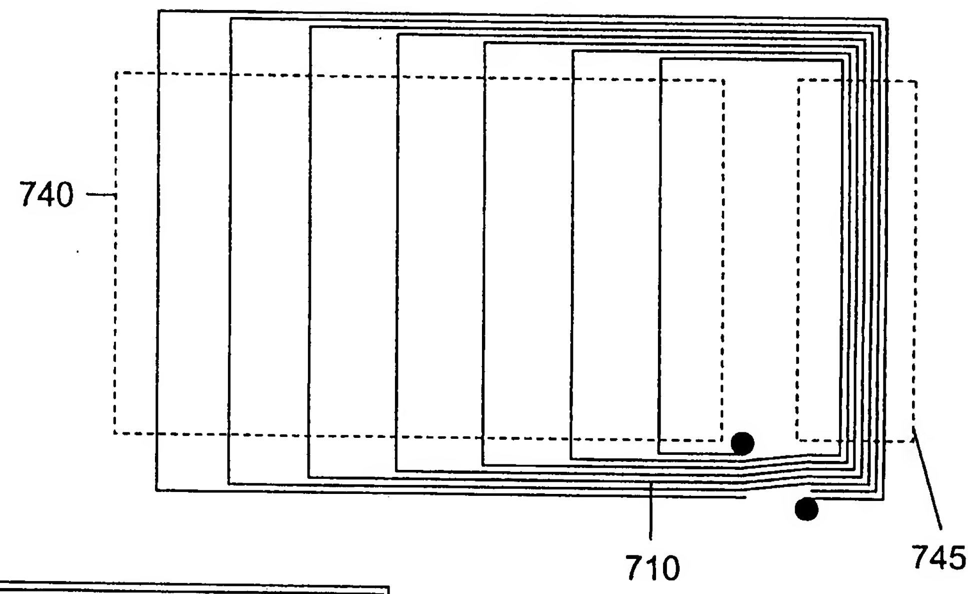

Figure 6a

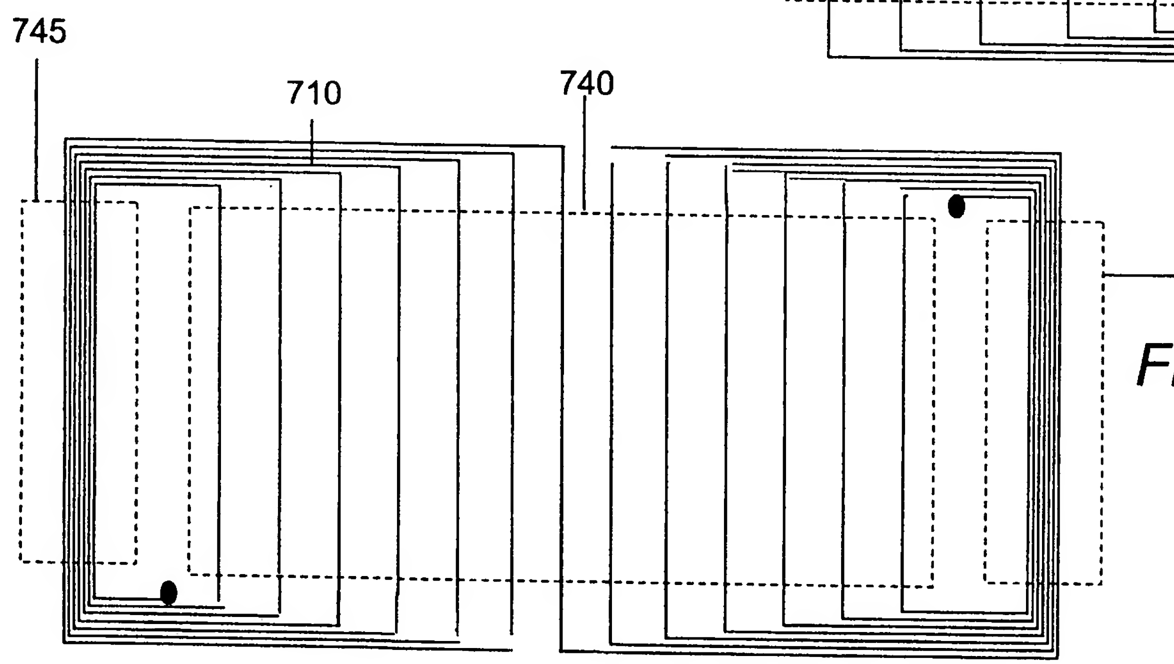

Figure 6b

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Figure 6c

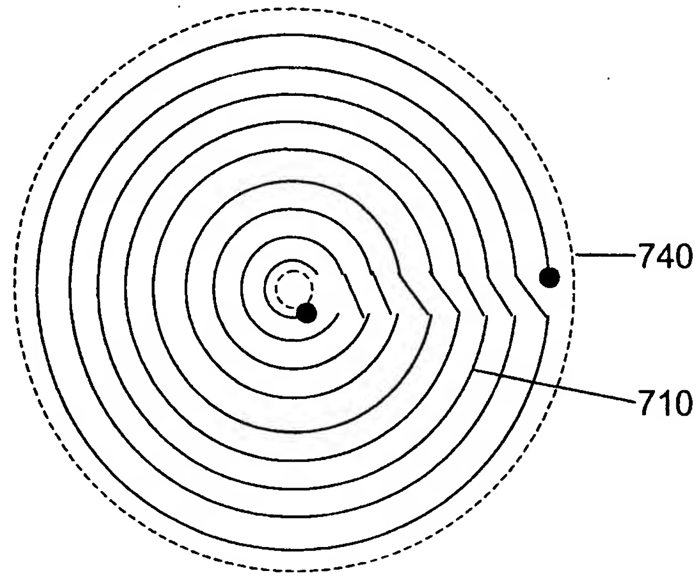


Figure 6d

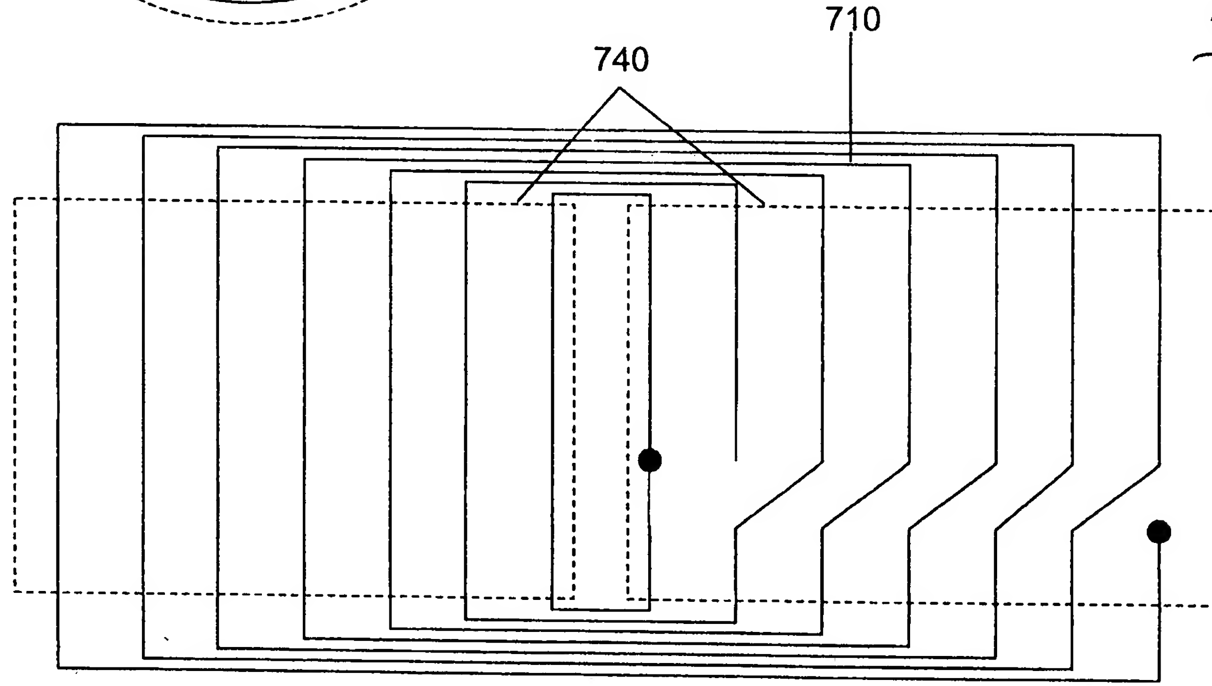


Figure 6e

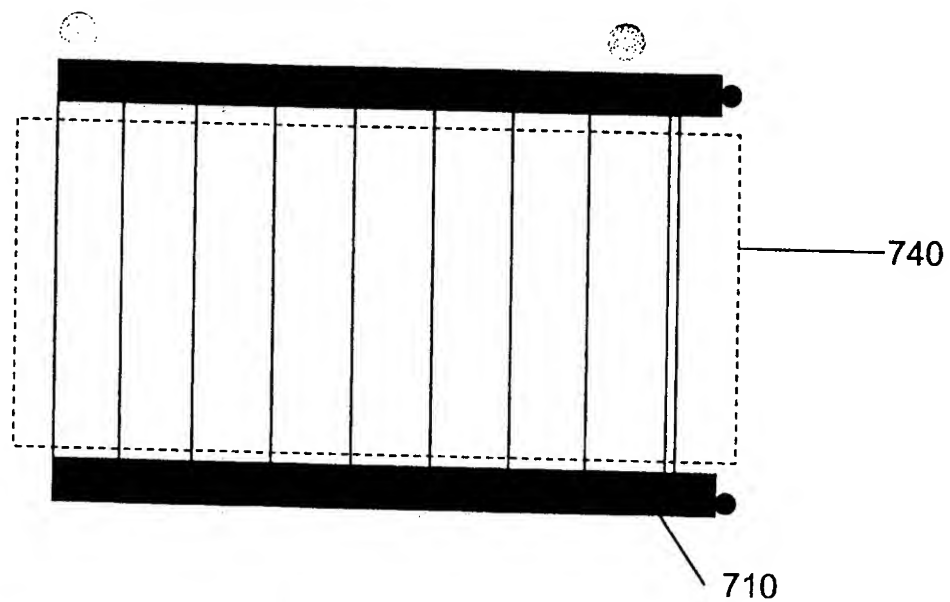
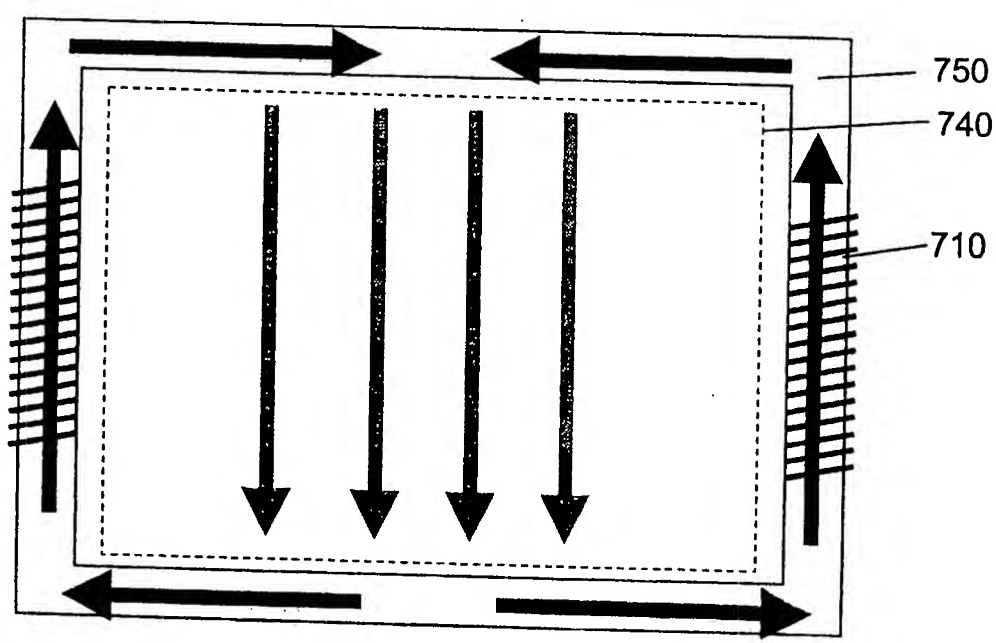


Figure 6f



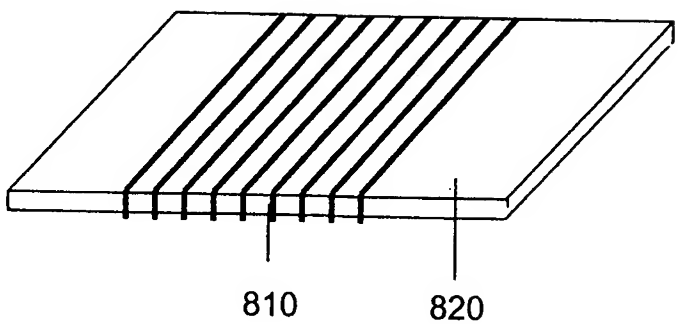


Figure 7a

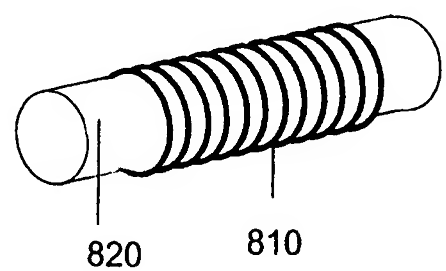


Figure 7b

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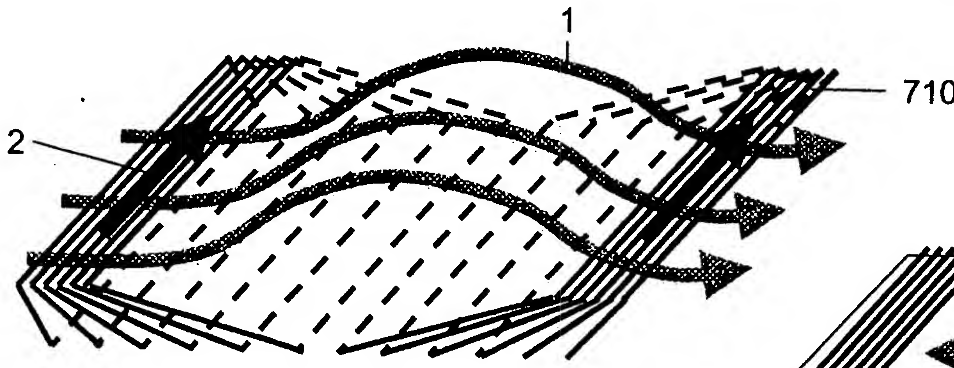


Figure 8a

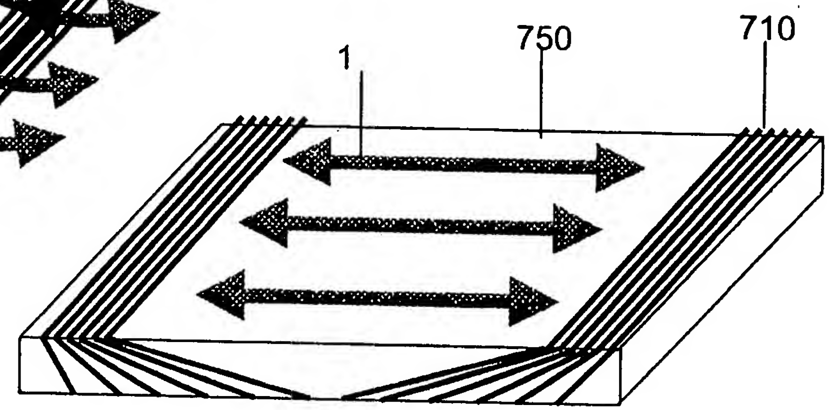
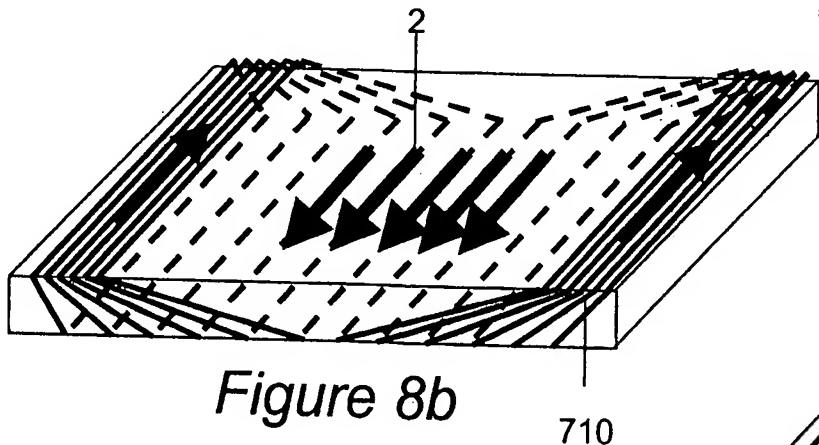


Figure 8c



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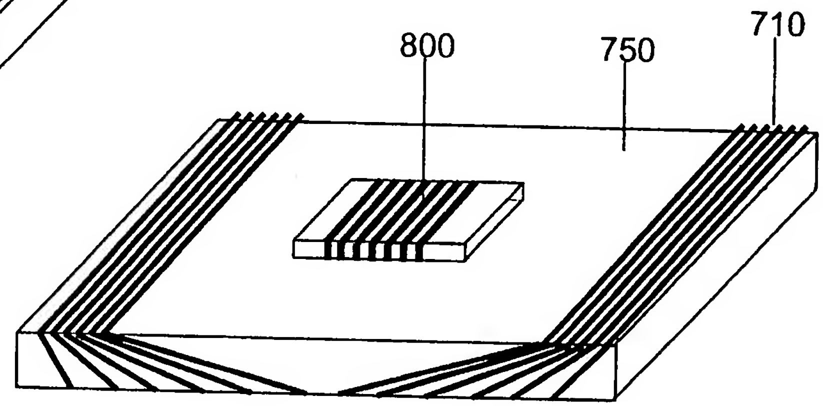

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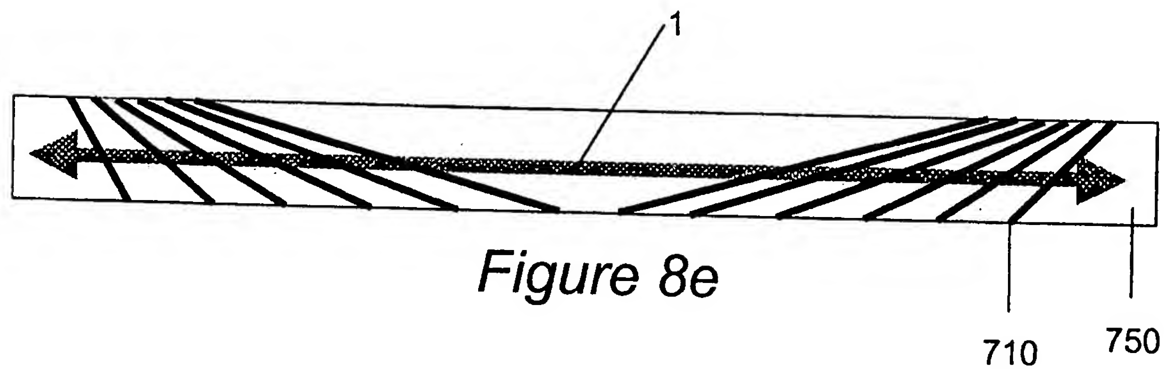

Figure 8e

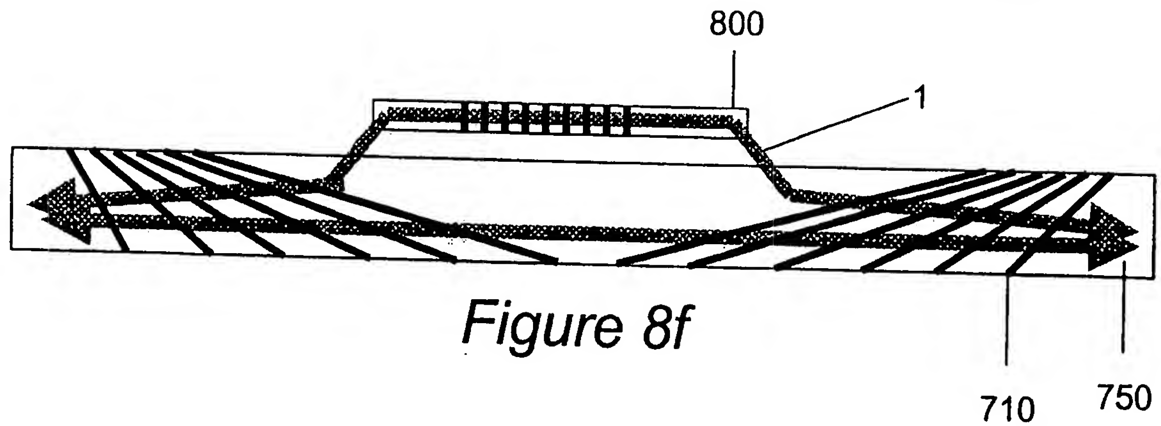

Figure 8f

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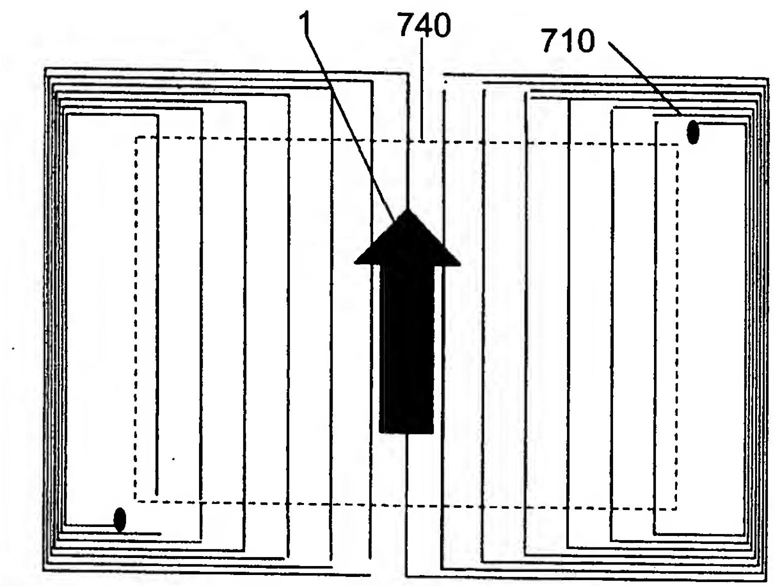
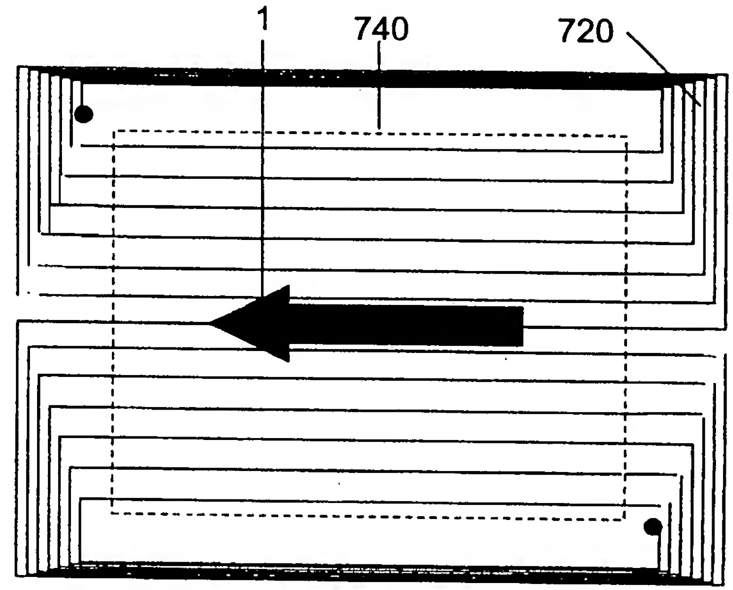


Figure 9a



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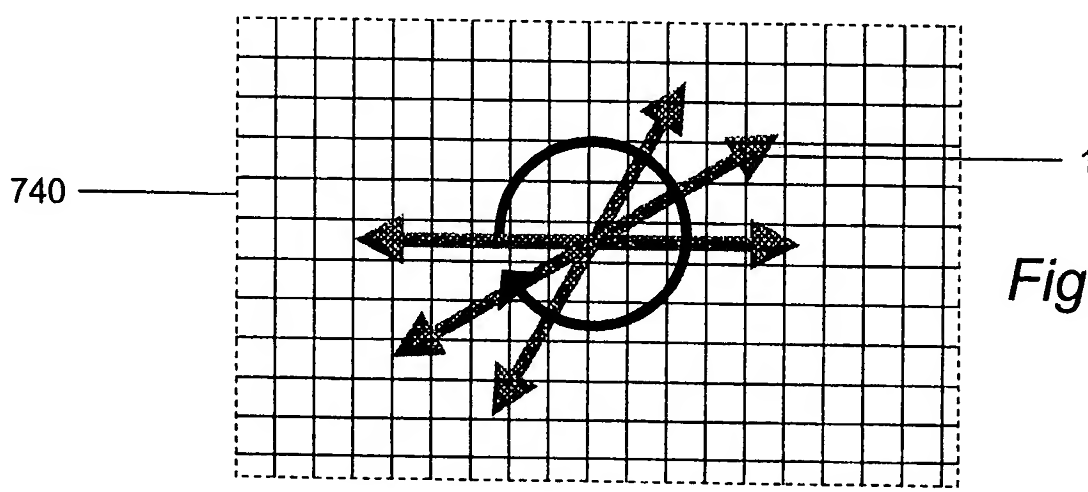
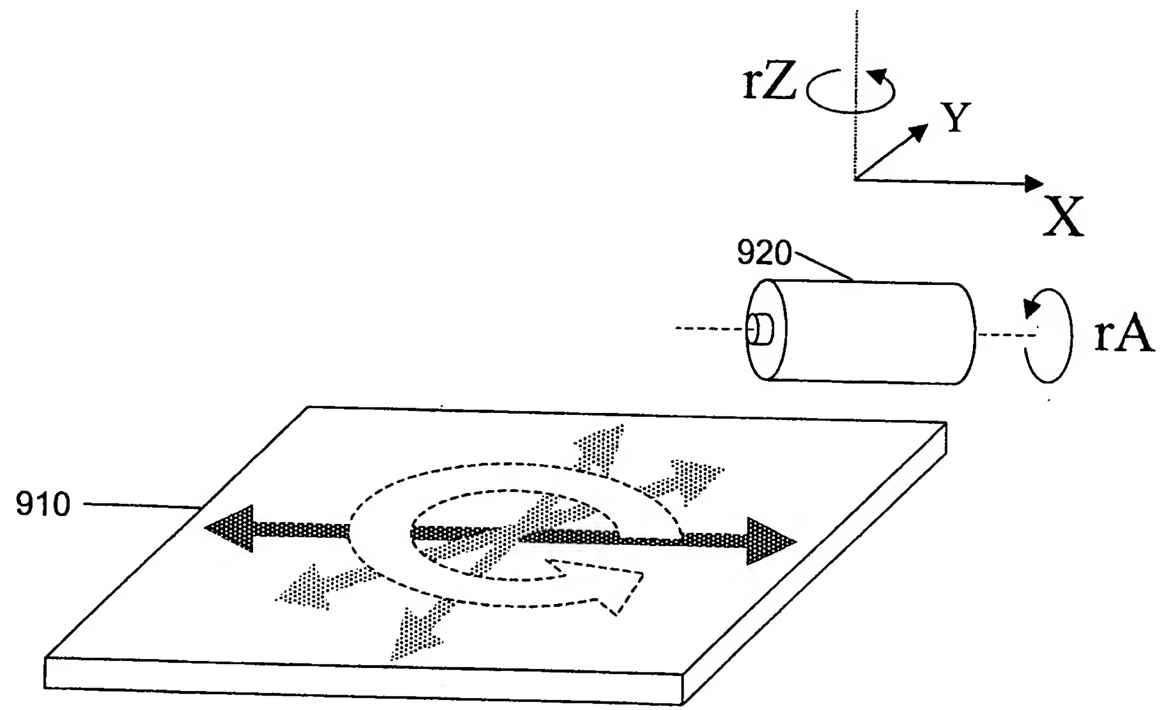


Figure 9c



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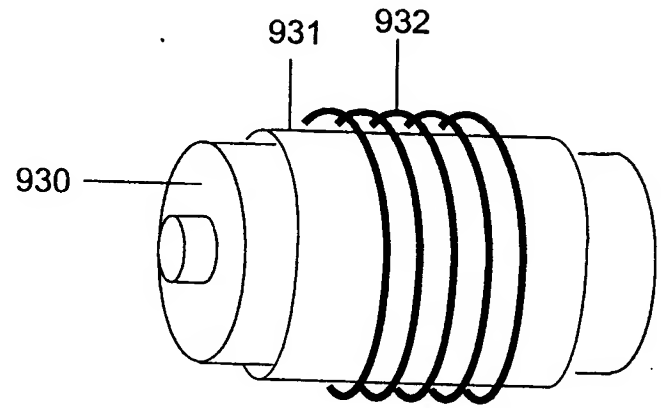

Figure 11a

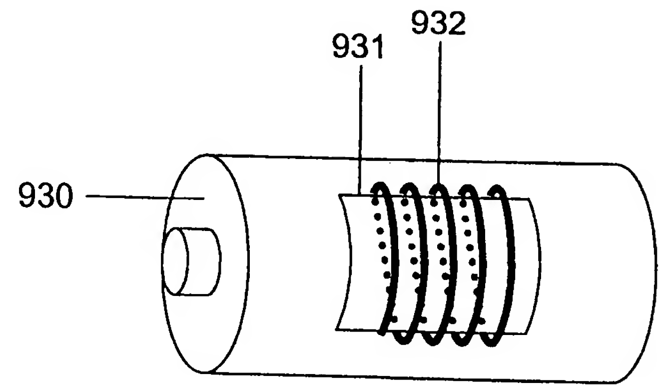

Figure 11b

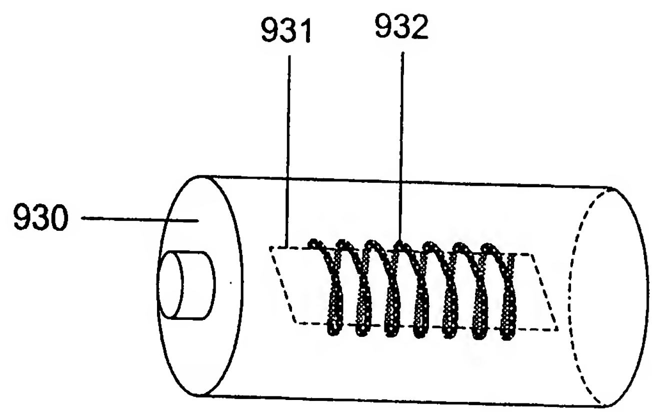

Figure 11c

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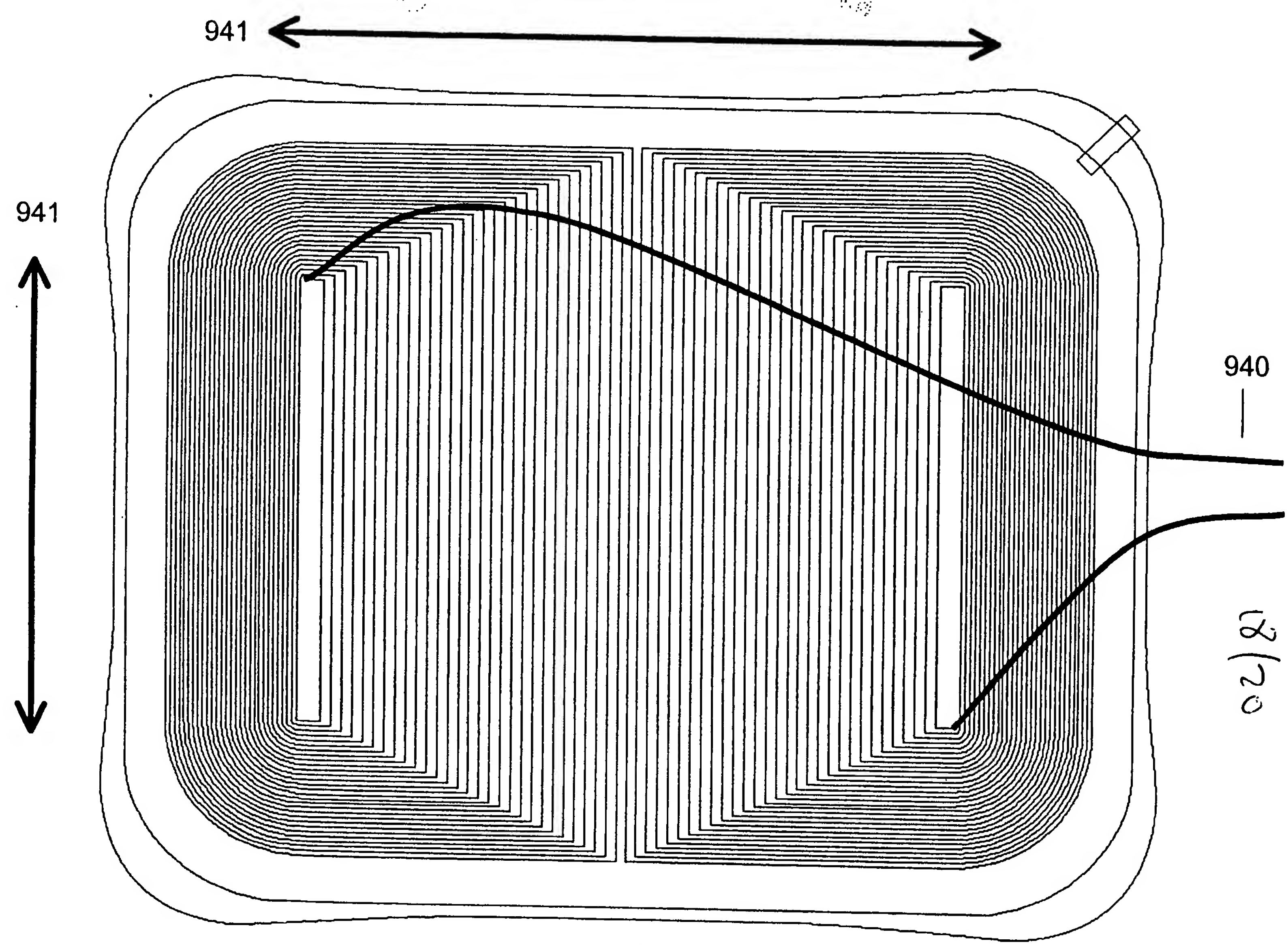

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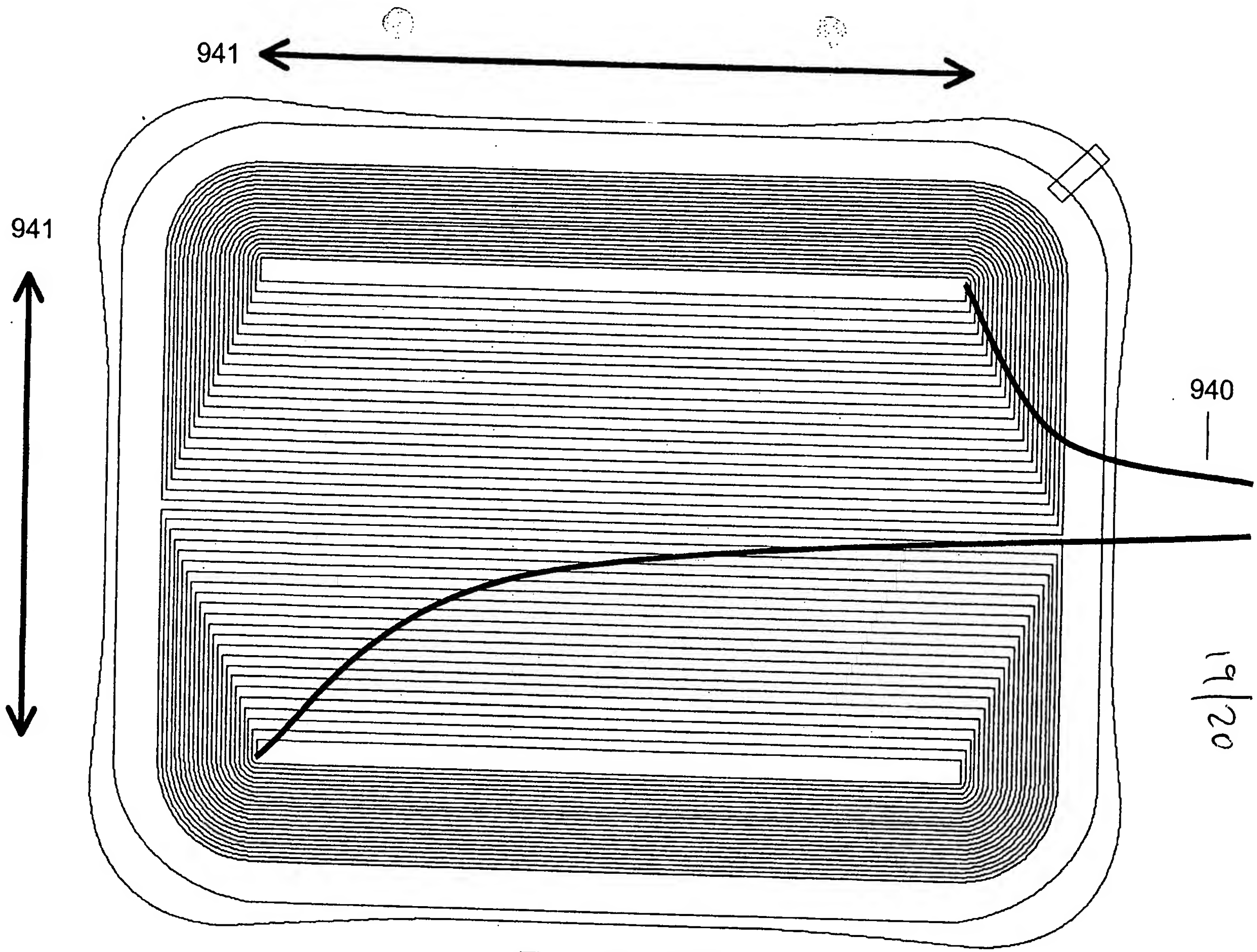

Figure 12b

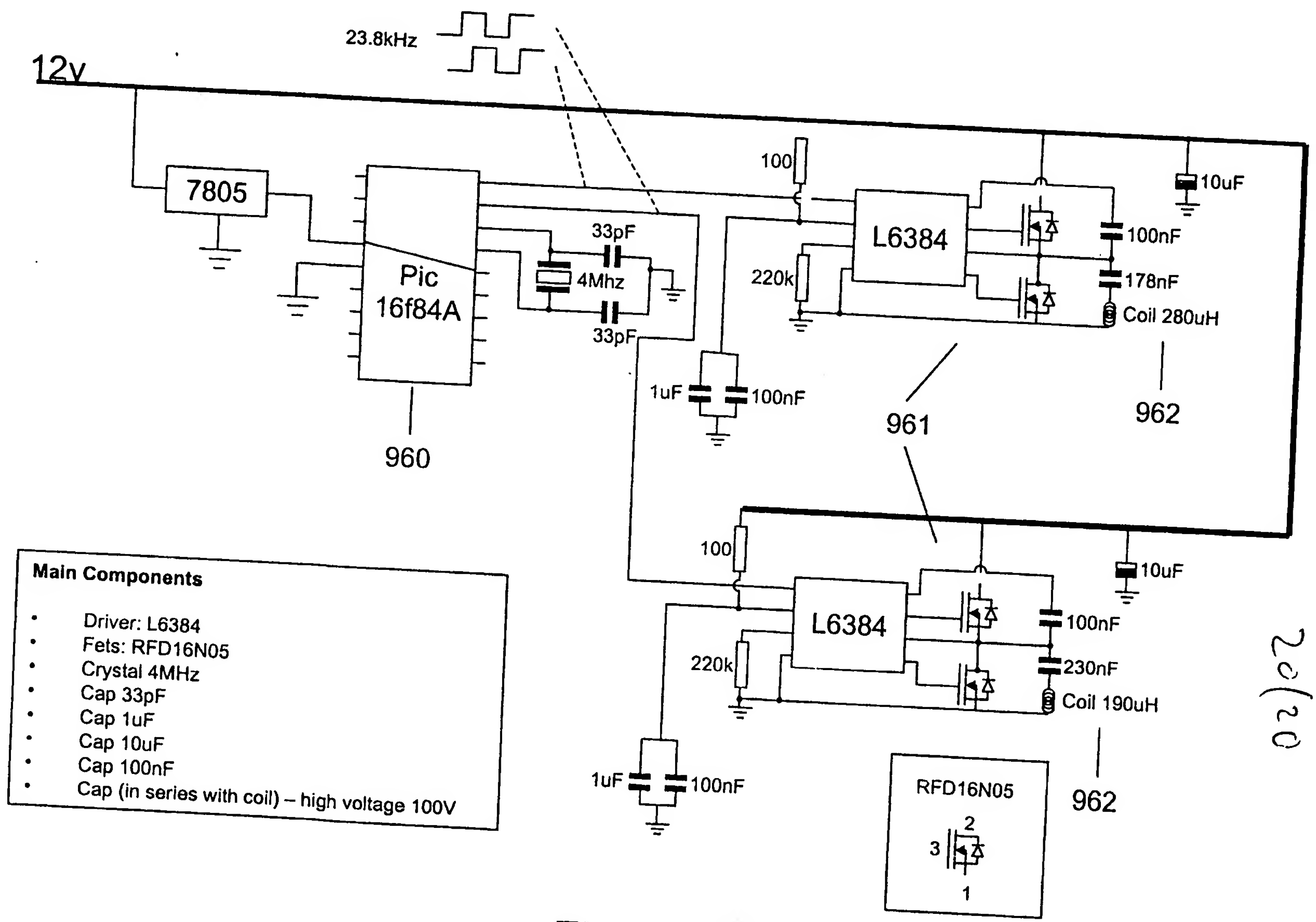
23.8kHz
12v
7805
Pic
16f84A
33pF
4Mhz
33pF
960
100
220k
L6384
1uF
100nF
10uF
100nF
178nF
Coil 280uH
961
962
100
220k
L6384
1uF
100nF
10uF
100nF
230nF
Coil 190uH
962
RFD16N05
2
3
1
Main Components
• Driver: L6384
• Fets: RFD16N05
• Crystal 4MHz
• Cap 33pF
• Cap 1uF
• Cap 10uF
• Cap 100nF
• Cap (in series with coil) – high voltage 100V

Figure 13